ASPECTS OF THE NICHE OF THE COMMON SNAPPING TURTLE, CHELYDRA SERPENTINA SERPENTINA, IN IOWA

An abstract of a Thesis by
Russell Ray Burken
October 1978
Drake University
Advisor: James L. Christiansen

The problem. Large gaps exist in knowledge of the niche of Chelydra s. serpentina in Iowa. Much of the literature is anecdotal and some is contradictory. Aspects of this turtle's niche investigated were growth and maturity, habitat preference, daily and seasonal activity cycles, response to a severe drought, population structure, home ranges, and homing ability.

Procedure. Turtles collected statewide and preserved were used in growth and maturity studies. A population of snapping turtles was monitored to provide information on the other aspects mentioned.

Findings. Growth is accomplished in an activity period of 204 days and a 145 day feeding period with growth beginning in late May. Most males are mature by the end of their fifth year at plastral lengths of 149-155 mm while most females are not mature until their seventh year at plastral lengths greater than 162 mm. Growth slows with maturity. Activity is greater at night. During severe drought snapping turtles are less active, burrow in mud or terrestrially, and move in association with rainy periods. They showed evidence of home ranges, homing ability, and most long distance movements were made in fall or spring. Apparently there is a sex ratio shift as snapping turtles mature.

Conclusions. Males mature before females. This late maturity of females may decrease the ability of snapping turtle populations to recover from exploitation by man. Snapping turtle behavior during drought presumably results in decreased mortality due to heat and desiccation. Snapping turtles appear to have home ranges that are large (1.33 ha), temporary (perhaps lasting a season), and overlapping implying that they are not strongly defended against other snapping turtles. They apparently have some homing ability.

Recommendations. More females need to be collected between ages five and eight, because further work on the apparent sex ratio shift is necessary. Also further study involving radio-telemetry, especially on the affect of season and sex on activity, would prove fruitful.

ASPECTS OF THE NICHE OF THE COMMON SNAPPING TURTLE, *CHELYDRA SERPENTINA SERPENTINA*, IN IOWA

A Thesis

Presented to

The School of Graduate Studies

Drake University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

---

by

Russell Ray Burken

October 1978

ASPECTS OF THE NICHE OF THE COMMON SNAPPING TURTLE, *CHELYDRA SERPENTINA SERPENTINA*, IN IOWA

by

Russell Ray Burken

Approved by Committee:

James L. Christiansen
Chairperson

Laurence E. Brown

Rodney A. Rogers

Dean of the School of Graduate Studies

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
MATERIALS AND METHODS	6
RESULTS	25
DISCUSSION	69
SUMMARY AND CONCLUSIONS	89
LITERATURE CITED	92

LIST OF TABLES

TABLE		PAGE
1.	Partial fauna list for the Chichaqua Wildlife Area.	17
2.	Age, sex, and size of transmitter-equipped *Chelydra serpentina*.	21
3.	Growth of 10 of 19 snapping turtles recaptured at Chichaqua Wildlife Area in 1976 and 1977.	26
4.	Age and size at maturity of Iowa *Chelydra serpentina* males.	29
5.	Age and size at maturity of Iowa *Chelydra serpentina* females.	31
6.	Movements of transmitter-equipped *Chelydra serpentina*.	56
7.	Date of captures and distance moved by recaptured *Chelydra serpentina*.	64
8.	Home ranges of *Chelydra serpentina* with five or more locations before and while marsh was dry.	66

LIST OF FIGURES

FIGURE		PAGE
1.	Localities in Iowa where Chelydra serpentina were obtained.	7
2.	Map of study area, Polk Co., Iowa.	9
3a.	Second left costal scute used in aging of snapping turtles.	11
3b.	Vertebral scute used in aging of snapping turtles.	11
4a.	Marsh before drought.	15
4b.	Marsh, following 7 July rain, during period marsh was dry.	15
5a.	Receiver, directional antenna, and prepared transmitter.	22
5b.	Chelydra serpentina with transmitter attached.	22
6.	Growth rates for Chelydra serpentina males calculated from carapacal annulae.	33
7.	Growth rates for Chelydra serpentina females calculated from carapacal annulae.	34
8.	Growth of combined sexes of Chelydra serpentina for different plastron length groups as calculated from carapacal annulae.	37
9.	Typical refuge for snapping turtles.	38
10.	Active beaver lodge.	39
11.	Movement of recaptured Chelydra serpentina at Chichaqua Wildlife Area, 1976-1977.	40
12.	Movement of TT 1.	41
13.	Movement of TT 2.	42
14.	Movement of TT 3.	43
15.	Movement of TT 4.	44
16.	Movement of TT 5.	45

FIGURE PAGE

17. Movement of TT 6. 46

18. Movement of TT 7. 47

19a. Transmitter-equipped turtle buried in mud, site disturbed by observer. 49

19b. Transmitter-equipped turtle buried terrestrially. 49

20. Chelydra serpentina activity in relation to rainfall at Chichaqua Wildlife Area 1977. 62

INTRODUCTION

The common snapping turtle (Collins et al., 1978), Chelydra serpentina, (LINNAEUS) is one of the most common and widespread turtles in the western hemisphere with a range extending from southern Canada to Ecuador (Feuer, 1971) assuming C. s. rossignoni and C. s. acutirostris are conspecific. Because the turtle has been implicated as a predator of waterfowl, its food habits have been extensively studied but large gaps of knowledge exist in other aspects of the niche it occupies and much of the literature concerning the turtle is anecdotal and some is contradictory. Various aspects of the turtle's niche in Iowa were studied, including growth and maturity, habitat preference, population structure, annual and daily activity cycles, response to a severe drought, home ranges, and homing ability.

Snapping turtles have several traits which make them difficult to study. Seldom is more than one caught in a trap, making it difficult to obtain specimens. All turtles are difficult to preserve and snapping turtles being among the larger of fresh water turtles are even more difficult. Snapping turtles, due to their large size and aggressive behavior, can be dangerous when handled, often inflicting a painful bite to careless handlers.

Several studies have appeared dealing with reproduction and/or sexual maturity of snapping turtles. Mosiman and Bider (1960) studying a Canadian population, and White

and Murphy (1973) studying a Tennessee population, concluded that the sexes mature at the same size. They based their criteria for maturity of females on presence of enlarged ovarian follicles. The former authors suggested that further work might indicate that females could mature at a smaller size than males. It is suggested that an extended sub-adult period occurs in this species in Iowa where ovarian follicles may enlarge considerably each spring at least two years before the turtle is capable of ovulation.

Growth was studied by Gibbons (1968a) in a polluted Michigan river, Hammer (1969) in South Dakota, and Graham and Perkins (1976) in a polluted Massachusetts marsh. These studies considered age and growth rate by combined sexes and did not investigate the relationship between growth rate changes and time of maturity of either sex separately. They indicated that snapping turtles lacked a rapid deceleration of growth at maturity. This investigation attempts to combine these factors and show how growth rate is related to turtle size, age, and state of maturity for each sex.

Several anecdotal accounts exist for snapping turtles preferring obstructed sites in other areas of its range but little is available on its habitat preference in Iowa. Pope (1939) found snapping turtles under submerged logs and Lagler (1943) found them in association with logs and stumps. Froese (1974) who studied space use in Tennessee found that juveniles showed some preference for obstructed

areas and adults congregated in areas with brush and rocks. The preference has been reported to be especially strong at times of hibernation (Clark and Southall, 1920).

There have been few reports on the annual activity cycle of snapping turtles. Cahn (1937) indicated that they were active from mid-May to October in Illinois. Gibbons (1968a) found Chrysemys picta entering traps from mid-March to October 1966 in Michigan. Cooper (1975) reported that Kinosternon flavescens spooneri was active for 106 days and had a feeding period of only 70 days. Mahmoud (1969) and Christiansen and Dunham (1972) reported activity cycles for K. f. flavescens of 140 days in Oklahoma and 183 days in New Mexico respectively. Ernst (1976) reported that the spotted turtle, Clemmys guttata, in southeastern Pennsylvania was active in all months but February, October, and November but only in large numbers during the spring (March through mid-June).

The periods of diurnal and nocturnal activity are not known for snapping turtles in Iowa. The literature suggests snapping turtles are active at night. Pope (1939), Wood (1953), and Ernst and Barbour (1972) all gave anecdotal accounts of nocturnal activity in snapping turtles. Froese (1974) following 11 transmitter-equipped snapping turtles found them to be significantly more active during night time hours. Murphy and Sharber (1973) monitored three transmitter-equipped Chelydra between July and November. They reported

no differences between nocturnal and diurnal activity.

Turtles are often faced with a drying of habitat. How they respond to this situation often determines survival. Cahn (1937) discussed the movement of Chelydra during periods of drought. He stated, "During seasons of excessive drought, they leave their native ponds as they dry up and with apparently unerring instinct travel overland to more congenial and habitable regions." Anderson (1942) reported Chelydra serpentina abandoning a Missouri lake but doubted if dry weather occasioned this. Cagle (1944b) found snapping turtles burrowed deeply in mud when the lake they were inhabiting suddenly dried up. Mahmoud (1969) found that Kinosternon flavescens flavescens, a xeric adapted turtle, aestivated when the temporary pools it inhabits dry during the summer.

Turtles have been shown to have home ranges (Cagle, 1944b; Moll and Legler, 1971; Froese, 1974; and Ernst, 1968b and 1976). Cagle (1944b) indicated non-random movement within an area. Moll and Legler (1971) defined home ranges as area used in normal daily activities excluding seasonal migrations. Various methods have been used to calculate home ranges, making comparison difficult. Moll and Legler (1971) indicated that home ranges of aquatic turtles are likely affected by the size and shape of aquatic habitat. Ernst (1968b) estimated the home range of snapping turtles at 1.88 ha but used a limited number of recaptures to

determine this. Froese (1974) found snapping turtles to have a home range averaging 216 m^2 but the pond used in the study was only 0.81 ha in area.

The literature suggests that the home ranges of some aquatic turtle species are temporary but little information about this is available with snapping turtles. Ernst (1976) found there was much shifting in the home ranges of Clemmys guttata between 1967 and 1974 and attributed this to the drying of the marsh forcing the turtles to new areas. Hammer (1969) found snapping turtles moved an average 0.07 miles in one summer but an average 0.57 miles between summers.

Some turtle species have been shown to have home sites or locations to which they return after foraging. Stickel (1950) called these sites "forms." Ernst (1976) reported that the spotted turtle, Clemmys guttata, often used muskrat burrows as the center of their home ranges, returning to them after periods of activity, as havens from danger and as hibernacula. In association with this homesite concept other authors have indicated that some turtles have homing ability or familiarity with their environment. Froese (1974) found snapping turtles rapidly returned to their homesites after being disturbed. Moll and Legler (1971) found some homing ability in the neotropical slider turtle, Pseudemys scripta, and Williams (1952) reported homing behavior in musk and painted turtles. Cagle (1944) found Pseudemys and Chrysemys displayed homing ability. Hammer (1972) found that

Chelydra moved to a new location did not usually remain there but did not indicate whether they returned to their old habitat.

The present study attempts to make a unified and systematic investigation of the following: growth rate and maturity, habitat preference, population structure, annual and daily activity cycles, response to severe drought, home ranges, and homing ability. Snapping turtles were collected throughout Iowa for the maturity and growth studies. A population of snapping turtles was monitored to provide data on the activity/population part of the study.

Insight into these problems was gained through analysis of 64 snapping turtles obtained throughout Iowa and deposited in the Drake University Research Collection. This analysis was initiated by Dr. James L. Christiansen and was completed jointly. The results were verified by field studies conducted at Chichaqua Wildlife Area and additional work there with 64 marked turtles and seven transmitter-equipped Chelydra yielded data on activity, home ranges, homing ability, response to a severe drought, etc.

METHODS AND MATERIALS

This investigation was conducted in two phases. Chelydra serpentina collected statewide (Fig. 1) by Dr. Christiansen and others from 1969 to 1977 were used in growth and maturity studies. Activity/population studies

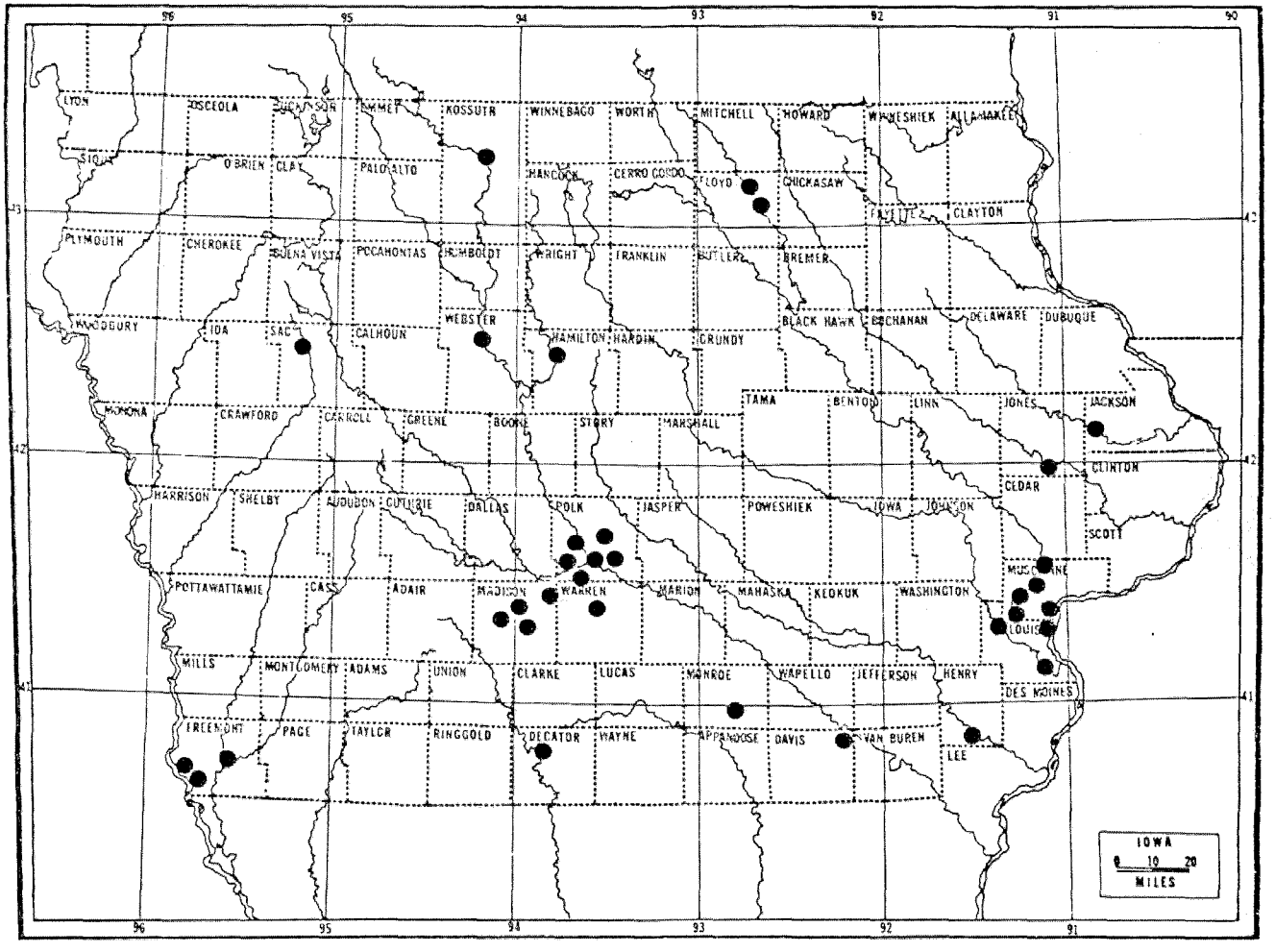

Fig. 1. Localities in Iowa where Chelydra serpentina were obtained.

were conducted with living turtles at the Chichaqua Wildlife Area (Fig. 2) from June to November 1976 and from April to November 1977. Growth and maturity data was also obtained from the latter.

Trapping methods. Snapping turtles collected with hoop nets as described by Legler (1960) were baited with either fresh fish or canned sardines. When collecting statewide, traps were set in the afternoon in suitable habitat and picked up the next morning. At Chichaqua, traps once placed at a location were left several days and checked and rebaited either each day (afternoon) or twice, both morning (600-800 hrs) and evening (1700-2000 hrs). Legler (1960) reported that bait decomposition is underway after 10 hours and that the traps are most effective the first two hours after baiting. Whenever possible, collections were made by hand, from fishermen, and by probing the mud with sticks.

Twenty-five males and 38 females were collected statewide and preserved. At Chichaqua, 64 snapping turtles were collected, marked, and released: 59 in 889 trap periods and five by other methods. A trap period is defined as at least an eight hour period between setting a trap and checking it. The Skunk River, which adjoins Chichaqua Wildlife Area, was trapped for a brief period, 18 July to 27 July 1977, for a total of 114 trap periods and yielded six snapping turtles.

Snapping turtles collected for growth and maturity studies were sacrificed by a cephalic injection of 70%

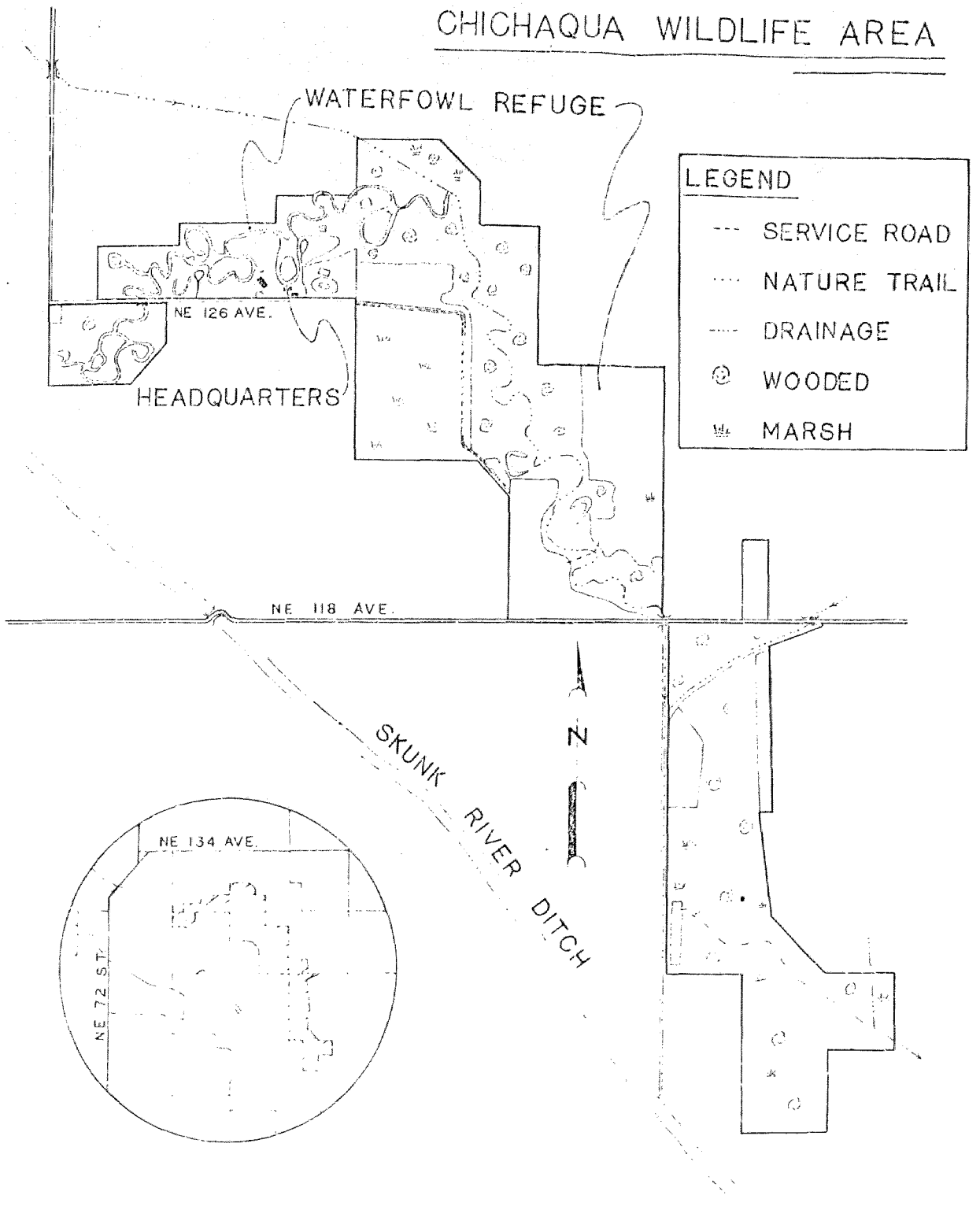

Fig. 2. Map of study area Polk Co., Iowa.

ethanol. Preservation was completed by the shell and soft parts method (Christiansen and Dunham, 1972). In this method, the shell, skin, intestinal tract, urogenital system, and apendicular skeleton were preserved and tagged separately. The skin, intestinal tract, and urogenital system were fixed in 13% formalin and then transferred to either 70% ethanol (skin) or 10% formalin (urogenital and intestinal systems). The shell and skeleton were cleaned and stored dry. All specimens were deposited in the Drake University Research Collection.

Criteria for maturity. Maturity was defined as the capability to produce mature gametes. Presence of motile epididymal sperm as determined from smears was the criterion used for males. Since some motile sperm were retained in the epididymides throughout spring and summer, this was an adequate character for maturity of male snapping turtles throughout the sampling period. Presence of ovulated eggs or corpora lutea was the criterion used for females. Because eggs are ovulated only in the spring and early summer, females taken at other times of the year which were as large as the smallest mature spring female were considered adult.

All aging was based upon clearly visible carapacal annulae. Most aging used the left second costal scute (Fig. 3a) and was verified by counts of annulae of the first left costal or adjacent vertebral scute (Fig. 3b). When annulae produced during the early years of growth were worn away, a

Fig. 3a. Second left costal scute used in aging of snapping turtles.

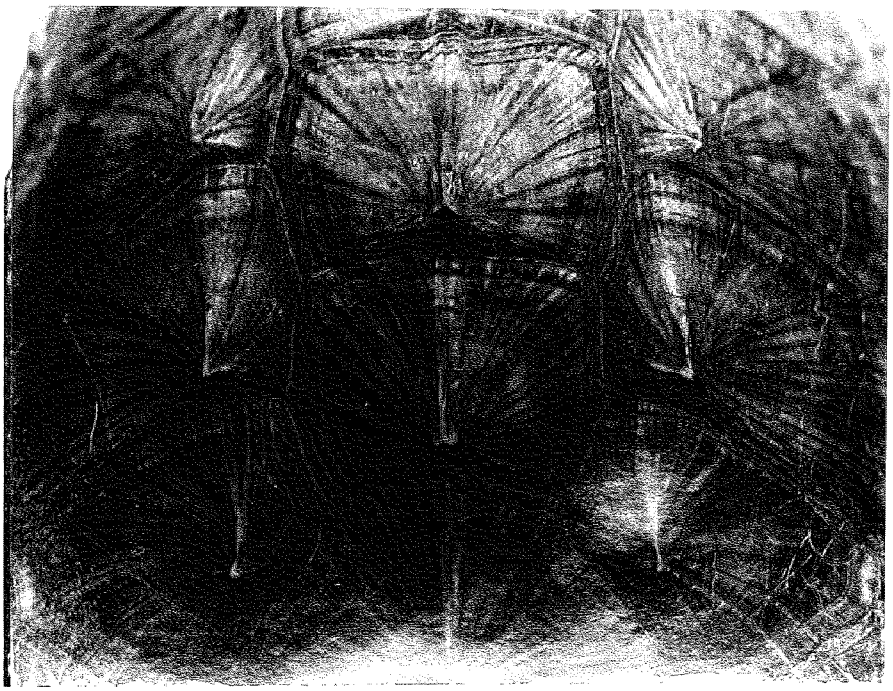

Fig. 3b. Vertebral scute used in aging of snapping turtles.

mean age was calculated for turtles with complete sets of annulae to the point of the first distinct annulus on the worn carapace. The mean age was then added to the number of annulae remaining on the worn scute to provide an estimate of the turtle's age. For example, if the second costal scute had 22 mm between the point of initiation of growth and the first visible annulus, and the mean of other turtles from the same locality was three years for the first 22 mm of scute growth, three years was added to the number of the remaining annulae to estimate the age of the turtle. All ages are given as complete years of growth and therefore exclude any growth the fall of the year of birth (hatchling year). All turtle measurements were made with a large set of calipers or with a meter stick to the nearest mm. Plastral measurements exckude the cartelagenous extension of the plastron.

Growth rates shown in figures were calculated only from turtles that were dissected and gonads examined. A rough calculation of the increments of plastral growth was made through measurements of each scute's growth by the following formula:

$$\frac{\text{Width of annular growth}}{\text{Total scute width}} = \frac{\text{Estimated plastral growth}}{\text{Total plastral length}}$$

The activity/population studies conducted at Chichaqua Wildlife Area in 1976 and 1977 consisted of three phases. A mark-recapture study was conducted in which snappers were captured, marked, measured, and released. A

radio-telemetry study was conducted in which seven snapping turtles were fitted with radio-transmitters and their movements and activities recorded. Observations were made that were incidental to the other two phases.

Most of the activity/population studies were conducted in that part of the refuge north of N. E. 126 Avenue (Fig. 2). This was the most accessible part of the refuge. It had the greatest number of water filled channels and during the low water periods of 1976 and 1977 was the only part of the area to hold sufficient water to have turtles in appreciable numbers.

The study area. Prior to the initiation of the activity/population study, Dr. Christiansen and others surveyed suitable Chelydra serpentina habitats in Iowa. Chichaqua Wildlife Area was surveyed using canoe and aerial photographs and it was determined the most suitable for the study. It contained a large population of snapping turtles, was centrally located, and was relatively typical of Iowa's snapping turtle habitat. The area is owned and controlled by the Polk County Conservation Board and is located nine miles north of Bondurant, Polk Co., Iowa. It consists of a series of oxbows of the Skunk River that was created following straightening of the river 70 years ago. The area is narrow and irregular in shape, generally following the course of the old Skunk River. It is approximately five km long (3.3 mi), has an area of 386 hectares (1200 acres), and has

approximately 15 km (9.3 mi) of channel. The area is managed mainly for hunting with some limited camping and other recreational use allowed. The only dwellings on the area are the ranger's house, office, machine shed, and rental lodge. It is surrounded on all sides by agricultural land except for the part adjoining the Skunk River.

The majority of the area is forrested, with willows (Salix sp.), white oak (Quercus alba), swamp oak (Q. bicolor), green ash (Fraxinus pennsylvanica), black locust (Robinia pseudo-acacia), and honey locust (Gleditsia triacanthos) being the dominant trees. Dogwood (Cornus sp.), black cherry (Prunus serotina), and buckthorn (Ramus cathartica) form the understory. A large part of the area north of N. E. 126 Ave. (Fig. 2) is wet prairie with brome grass (Bromus sp.) dominant and some big bluestem (Andropogan geradi).

The channel areas have received large amounts of sediment over the years. A whisky still deposited in a pool north of the area buildings by local inhabitants during a 1930s raid by federal agents is now completely covered. The substrate of the channels is soft organic mud, in which a person sinks an average of 25 cm.

During periods of normal rainfall the water level fluctuates between 0.8 m and 2 m, averaging 1.2 m (Fig. 4a). Years 1976 and 1977 were not normal in that below average precipitation was recorded for both years. During summer 1976 the water level dropped to 0.3 m and remained at that

Fig. 4a. Marsh before drought.

Fig. 4b. Marsh, following 7 July rain, during period marsh was dry.

level during the winter 1976-1977. Because of low water level and very cold weather of winter 1976-1977 a large fish kill occurred resulting in the removal of nearly all fish species listed in Table 1. A kill of turtles Chrysemys picta, Trionyx spinnifera, and Chelydra serpentina also resulted. The drought continued in 1977, although the water level rose briefly in spring to the normal low water level (0.8 m) found in late summer of other years. After this brief rise, the water level continued to drop until the marsh was dry about 25 June 1977 (Fig. 4b). At this time there were less than seven cm (4 inches) of water in most of the channels creating the worst drought in the 70 year history of the area. This condition continued until August 1977 when substantial rains occurred and the water level began to rise. From 10 August to 15 September 1977 the water level rose 1.5 m (4 ft).

Due to the fish kill of winter 1976-1977 a luxuriant bloom of waternet (Hydrodiction sp.) occurred during the brief rise in water level in the spring. At the peak of the bloom it was so dense that a canoe could not be used. Large numbers of arrowheads (Sagitarius latifolia) and cattails (Typha latifolia) also appeared.

Life in the area is abundant and varied. A partial list of life found in the area appears in Table 1. The area had a particularly dense population of beavers (Castor canadensis) at the time of the study.

Table 1. Partial Fauna List for the Chichaqua Wildlife Area.

Fishes
- carp (Cyprinus carpio)
- bigmouth buffalo (Ictiobus cyprinellus)
- black bullhead (Ictalurus melus)
- yellow bullhead (I. natalus)
- green sunfish (Leponis cyanellus)
- bluegill (L. macrochirus)
- pumpkinseed (L. gibbosus)
- black crappie (Pomoxis negromaculatus)
- white crappie (P. annularis)
- largemouth bass (Micropterus salmoides)
- white sucker (Catostomus commersoni)
- gizzard shad (Dorosoma cepedianum)
- mooneye (Hiodon tergisus)
- quillback carpsucker (Carpoides cyprinus)

Amphibians
- northern leopard frog (Rana pipiens)
- plains leopard frog (R. blairi)
- green frog (R. clamitans)
- bull frog (R. catesbiana)
- blanchard's cricket frog (Acris blanchardi)
- gray treefrog (Hyla versicolor)
- american toad (Bufo americanus)
- tiger salamander (Ambystoma tigrinum)

Reptiles
- garter snake (Thamnophis sirtalis)
- plains garter snake (T. radix)
- ribbon snake (T. saurítus)
- fox snake (Elaphe vulpina)
- northern brown snake (Storeria dekayi)
- northern watersnake (Natrix sipedon)
- graham's watersnake (Regina grahami)
- snapping turtle (Chelydra serpentina)
- spiny softshell turtle (Trionyx spinnifera)
- western painted turtle (Chrysemys picta belli)
- blandings turtle (Emydoidia blandingi)

Birds
- great blue heron (Ardea herodias)
- green heron (Butorides virescens)
- kingfisher (Megaceryle alcyon)
- baltimore oriole (Icterus galbula)
- goldfinch (Spinus tristus)
- redwinged blackbird (Agelarus phoeniceus)
- great-horned owl (Bubo virginianus)
- barred owl (Strix varia)

Table 1. (continued)

Birds (continued)
sparrow hawk (*Falco sparverius*)
mallard duck (*Anas platyrnychos*)
blue-winged teal (*A. discors*)
wood duck (*Aix sponsa*)
canada goose (*Branta canadensis*)
redheaded woodpecker (*Melanerpis erythrocephalus*)
bluebird (*Sialia sialis*)
Mammals
white-tailed deer (*Odocoileus virginianus*)
raccoon (*Procyon lotor*)
opossum (*Didelphis marsupialus*)
red fox (*Vulpes fulva*)
beaver (*Castor canadensis*)
muskrat (*Ondontra zibethica*)
short-tailed shrew (*Blarina brevicauda*)
eastern mole (*Scalopus aquaticus*)
franklin ground squirrel (*Citellus franklinii*)
thirteen-lined ground squirrel (*C. tridecemlineatus*)
fox squirrel (*Sciurus niger*)
prairie vole (*Microtus ochrogaster*)
mink (*Mustela vison*)

Mark-recapture methods. Snapping turtles captured at Chichaqua were measured by use of 65 cm calipers to the nearest mm for carapace length, plastral length, and width (at seven marginal scute). Turtles ages were roughly determined by counts of annulae (Fig. 3a) and the second left costal scute and verified by counts of vertebral scutes (Fig. 3b). Sex was determined by measuring precloacal length (Mosiman and Bider, 1960; White and Murphy, 1973). Capture locations were plotted on area maps. Each turtle was then marked by filing notches in the marginal scutes according to a numbering scheme modified from Ernst et al., (1974). This allowed individual turtles to be identified upon recapture and gave data on movements, population density, and growth. Turtles were released at point of capture within 28 hours. Whenever possible, the time turtle entering a trap was recorded (night vs. day). During the study, traps were placed at regular intervals along the shoreline as water level permitted. During the most severe part of the drought only five traps could be used in the two small pools with water deep enough to set traps. Over 100 Chrysemys picta were also marked during the study.

Snapping turtles can inflict a painful bite thus turtles being handled were restrained with a rope (Ernst et al., 1974). In this method turtles were allowed to bite the rope which was then tied under the posterior edge of the carapace with the rope holding the head in.

Population levels were determined by use of the Lincoln Index (Mosby, 1963). The population size (N) was calculated by the equation:

$$N = Mn/m$$

where M is the number of marked turtles, n is the total number caught during the period, and m is the number of marked turtles recaptured. The stardard error was calculated by the formula (Ernst, 1976):

$$SE = \sqrt{\frac{M^2 n(n - m)}{m^3}}$$

The population limits were set by adding and subtracting two standard errors (95% confidence level) from the estimated population size (N).

Radio-telemetry study. Radio transmitters purchased from Mini-Mitter Corp. Inc. were placed on seven snapping turtles (Table 2). Two were followed in 1976 (19 July to 2 November) and six in 1977. One turtle was followed for part of both years. The transmitter and battery were enclosed in a plastic capsule 50 by 10 mm. For waterproofing, five coats of butyrate dope was applied to the transmitter followed with a coat of epoxy glue added as a break in the leakage path. A copper bell wire harness was then wrapped around the transmitter and five more coats of butyrate dope were applied. The transmitter (Fig. 5a) was then attached to the snapping turtle by drilling a hole in the 11th and 12th scutes and running the free wires of the harness through

Table 2. Age, sex, and size of transmitter-equipped Chelydra serpentina. A = adult; SA = subadult

Turtle number	Capture date	Age (years)	Sex	Carapace length (mm)	Plastron length (mm)
TT 1	16 July 1976	8	male(A)	216	173
TT 1	30 June 1977	9	male(A)	226	179
TT 2	11 Aug. 1976	8	female(SA)	200	161
TT 3	16 April 1977	12	male(A)	271	209
TT 4	1 May 1977	8	male(A)	253	191
TT 5	1 June 1977	7	female(A)	229	176
TT 6	8 July 1977	14+	male(A)	311	242
TT 7	2 Aug. 1977	14+	male(A)	300	220

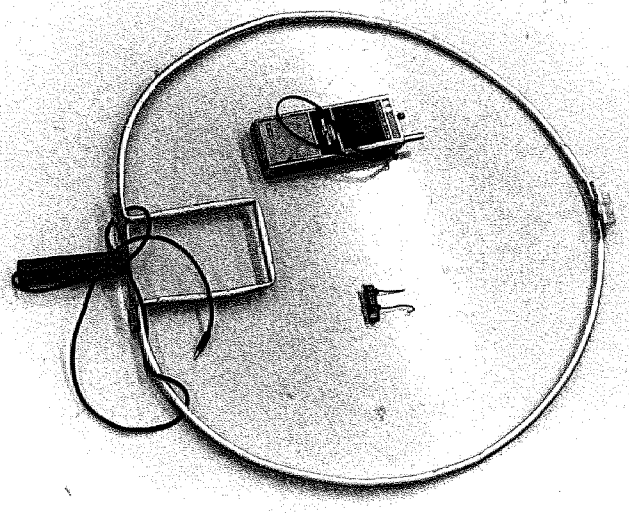

Fig. 5a. Receiver, directional antenna, and prepared transmitter.

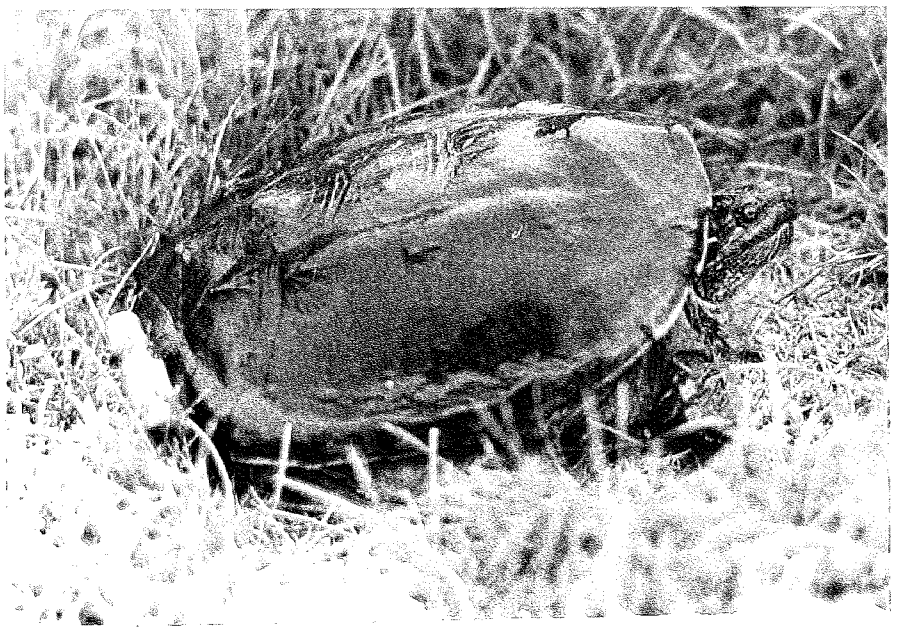

Fig. 5b. Chelydra serpentina with transmitter attached.

the holes in the carapace. The wires were twisted together affixing the transmitter to the turtle (Fig. 5b).

The transmitters emitted an intermittant signal with a range of 200 m under optimal conditions. Each transmitter emitted on a different frequency, 27.555 to 27.615 mHz, so individual turtles could be identified. Average transmitter life was two months and at that time as it became possible, the transmitter was replaced.

Receiving equipment consisted of a modified walkie-talkie (Lafayette model HA-420) equipped with either a whip or a hand held directional antenna (Fig. 5a). Each receiver had three channels allowing three turtles to be located before crystals had to be changed.

Approximate location of transmitter-equipped turtles (TTs) was determined by walking or canoeing the area until a signal was heard. At this point, during the first year of the study, they were located further by use of the directional antenna. In the second year of the study it was found that the TTs could be more accurately and easily located by reducing the length of the whip antenna thus reducing the receptivity. With the whip antenna fully withdrawn, the range was seven meters and within 0.5 m of the transmitter the signal change to a dull thud. They could thus be located to within 0.3 m (1 foot). The directional antenna was not used in 1977.

When these turtles were located, an attempt was

made to relocate them within one hour. Periodically during the second year they were monitored continuously throughout the day or night. While the marsh was dry (25 June to 10 August) small branches were positioned in front of and behind the carapace of buried TTs, so that they could not leave and return without the movement being noticed.

Home ranges were determined by summing the channel areas that included all recorded locations for each turtle. The circular (Fitch, 1958) or the convex polygon (Froese, 1974) methods were not used. In the circular method (radius), the home range is determined by using the average distance between locations as the radius of a circle for which area is then calculated. A convex polygon is constructed by connecting points of locations so that all further points are included within the area enclosed. Because of the very irregular shape of the aquatic environment at Chichaqua, use of these would have probably falsely implied that most of the range of the snapping turtles was terrestrial.

Observations were made of rainfall, temperature, and other turtle species behavior. Aspects of snapping turtle behavior were noted such as, nature of burrowing, time and nature of basking, and time of nesting. Snapping turtle tracks were noted since they were the only turtle track in the area where the tail leaves a distinct mark as they move across mud.

RESULTS

Growth and maturity. Turtle movement was first observed 9 March and the latest was seen on 28 September giving an observed activity period of 204 days. Turtles did not feed sufficiently aggressively to be attracted to baited traps until 16 April and the latest trapping record was 7 September, providing a feeding and estimated growing period of 145 days. Table 3 summarizes the growth and aging data for turtles with recaptures more than 25 days apart. Data of two turtles with shorter recapture spans are included because the spans encompass the period of initiation of spring growth and distinguishing of the last winter's scute indentation.

Virtually no growth occurred between 1 October and 11 May as indicated by the first five specimens listed on Table 3. That some growth may occur the last weeks of September, possibly from stored energy, is demonstrated by specimen eight. The first spring growth occurs between 17 and 25 May when the winter's scute indentation is distinguished, resulting in one "year" being added to the turtle's age as is indicated by specimens 8, 16, and 17. The most rapid shell growth occurred in June, July, and August as seen in specimens 2, 3, 8, and 19. Specimen 15 showed no growth during May and June. It is suspected that this turtle was considerably older than the 7 to 8 years assigned to it. All scutes were extremely worn and

Table 3. Growth of 10 of 19 snapping turtles recaptured at the Chichaqua Wildlife Area in 1976 and 1977. Most turtles are excluded where the only recaptures are 25 days or less apart.

Turtle No.	Date of Capture	Age	Sex	Plastral length	Carapace length
8	6 Aug. 1976	4	juv	93	125
	7 Aug. 1976	4		93	125
	7 Aug. 1976	4		93	125
	18 Sept. 1976	4		103	128
	17 May 1977	4		105	132
	2 Aug. 1977	5		119	156
9	13 Aug. 1976	6	juv	163	195
	11 May 1977	6		163	195
16	17 May 1977	3	juv	123	157
	25 May 1977	4		124	159
17	20 May 1977	6	juv	151	195
	3 June 1977	7		152	196
18	6 Sept. 1976	6	juv	150	189
	17 April 1977	6		150	190
14	10 March 1977	15++	male	271	365
	2 April 1977			271	365
15	1 May 1977	7-8?	male	191	253
	7 July 1977	7-8?	male	191	253

Table 3. (continued)

Turtle No.	Date of Capture	Age	Sex	Plastral length	Carapace length
2	16 June 1976	6	juv	133	168
	18 June 1976	6		133	168
	30 July 1976	6		139	171
3	27 June 1976	4	juv	94	120
	30 July 1976	4		102	127
19	16 July 1976	8	male	173	216
	6 Aug. 1976	8		174	219
	30 June 1977	9		179	226

assignment of a precise age was not possible. Specimen 14 also showed the slow growth of old turtles.

The most questionable data used to calculate growth rates comes from estimates of age on the basis of scute annulae. In this study shallow annulae were observed probably associated with dry periods or other minor environmental fluctuations. An attempt was made to recognize all of these and exclude them from age estimates. Studies of the marked Chichaqua population confirm the appearance of a single annulus the last two weeks of May and no other comparable annulae during the remainder of the year. A drought occurred during 1976 and 1977 resulting in decreasing water level until all but a few shallow pools were dry. An August recapture (specimen eight) showed 14 mm of plastral growth between 17 May and 2 August during this dry period (25 June to 10 August) and no extra annulus comparable with those produced by winter hibernation.

Male snapping turtles from Iowa begin to mature at about 135 mm PL, 191 CL, and in their fourth full growth year of life (Table 4). The oldest immature male was in its fifth year, 154 mm PL, 223 CL. The youngest mature male was in its fourth year, 155 mm PL, and 213 mm CL, and the smallest in its fifth year, 149 mm PL, and 191 CL. It is evident that nearly all males clearly are mature by the end of their fifth year of life.

Female snapping turtles show little ovarian development

Table 4. Age and size at maturity of Iowa Chelydra serpentina males. J=immature; S.A.=immature with enlarging testes and epididymides; A=mature.

Plastral Length (mm)	Carapace Length (mm)	Age (Years)	Maturity
65	91	1	J
90	125	1	J
100	137	3	J
100	144	3	J
119	172	4	J
123	166	2	J
135	198	5	SA
149	191	5	A
154	223	5	SA
155	213	4	A
158	207	4	SA
162	221	5	A
163	241	7	A
165	240	4	A
169	248	7	A
170	224	6	A
172	244	12	A
177	251	7	A
185	265	20	A
189	256	10	A
194	277	20	A
196	261	16	A
200	297	20	A
204	248	9	A
216	331	35	A
221	305	35	A
231	355	11	A

in Iowa until their fourth year (Table 5) when they range from 123-140 mm PL and 158-191 mm CL (Table 5). Between years four and seven, follicular enlargement occurs with some follicles growing to five mm diameter or more as the turtles enter a sub-adult phase. While an occasional ovarian follicle may be considerably enlarged, no corpora lutea or corpora albicantia were ever observed in these turtles. Their oviducts became opaque but were never as large as in reproductive females and the turtles ranged from 123-175 mm PL and 158-232 mm CL. The youngest mature female turtle was entering its sixth year of life (193 mm PL, 250 mm CL), but was considerably larger than other adults apparently as much as five years older. The oldest certainly immature turtle was in its tenth year (175 mm PL, 232 mm CL) and larger than the smallest adult (172 mm PL, 211 mm CL), the latter appearing to be in its 11th year of life. Our data therefore indicate that while a rare individual may become mature in its sixth year, most do not ovulate until they are at least in their seventh or eighth year and larger than 172 mm PL, and 229 mm CL. This is two to three years later than maturation of males.

Growth rate was about the same for the two sexes or slightly greater for females until they attained plastral length of about 50 mm (Figs. 6 and 7). After that period males grew more rapidly. In addition, it was usually possible to estimate the age of male turtles to 20 years or

Table 5. Age and size at maturity of Iowa Chelydra serpentina females. J=immature; SA=immature with ovarian follicles 2.5 mm; A=mature adult; CL=corpora lutea present; F + numeral=largest follicle diameter; OE=oviducal eggs.

Plastral length (mm)	Carapace length (mm)	Age	Maturity	Most advanced ovarian condition
57	76	1	J	F < 1mm
64	83	1	J	F < 1mm
68	92	1	J	F < 0.5mm
71	103	1	J	F < 1mm
79	101	2	J	F < 0.2mm
83	114	2	J	F < 1mm
85	117	2	J	F < 0.6mm
95	127	2	J	data lost
102	132	3	J	F < 1mm
103	135	3	J	F < 1mm
111	158	3	J	F < 1.1mm
113	156	5	J	F < 1mm
116	165	2	J	F < 1mm
116	168	2	J	F < 1mm
123	158	4	J	F < 2.5mm
123	166	4	J	F < 2.5mm
129	166	6	SA	F < 3mm
129	170	4	J	F < 1mm
135	194	4	J	F < 2.5mm
139	191	4	J	F < 2.5mm
140	183	4	SA	F < 3mm
143	230	7	SA	F < 2.9mm
149	199	5	J	F < 1.5mm
155	201	5	J	F < 2mm
159	194	8	SA	F 5.1mm
160	212	5	SA	F 4.4mm

Table 5. (continued)

Plastral length (mm)	Carapace length (mm)	Age	Maturity	Most advanced ovarian condition
162	229	6	SA	F 4.8mm
164	196	6	J	F < 1mm
172	211	11	A	CL
175	232	10	SA	F 6.5mm
183	258	11	A	OE
186	231	11	A	CL
186	271	>15	A	gonads destroyed
193	250	6	A	CL
193	254	>15	A	CL
204	268	8	A	CL
212	294	13	A	OE
215	259	>15	A	CL

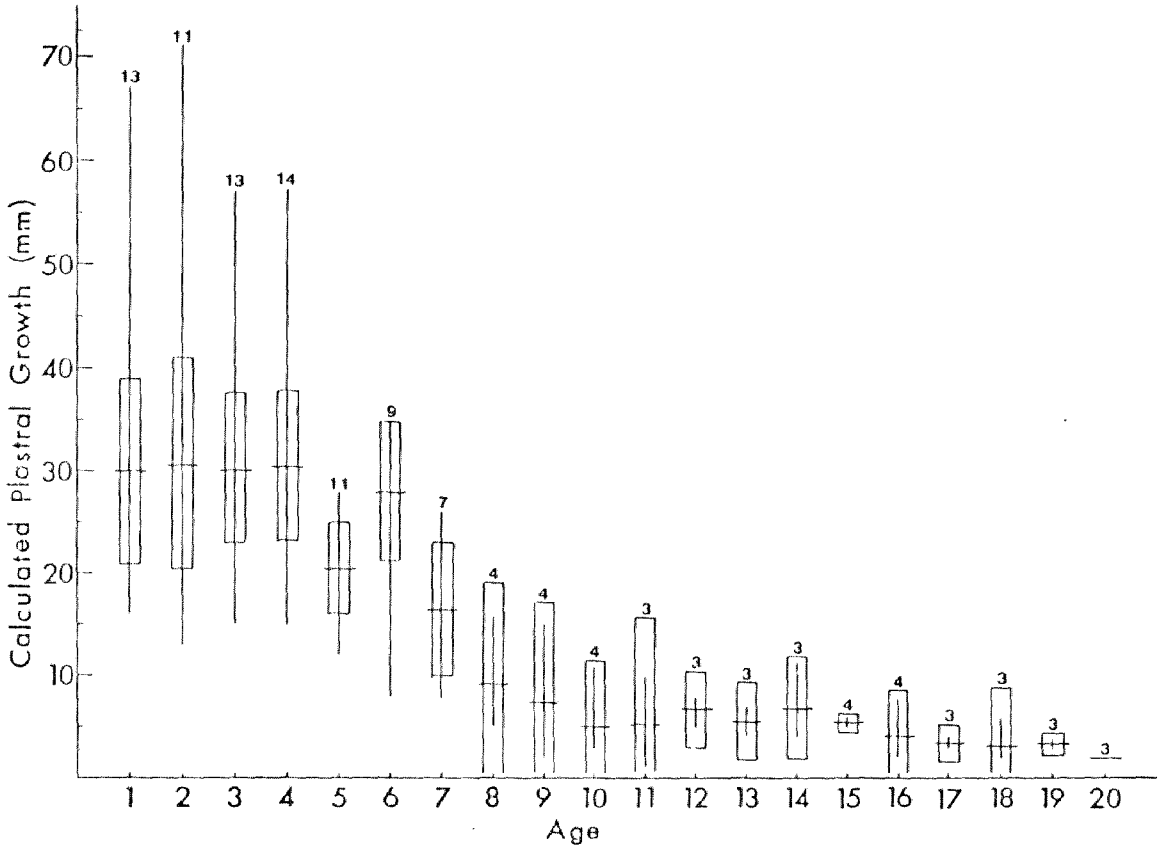

Fig. 6. Growth rates for Chelydra serpentina males claculated from carapacal annulae. Vertical bars represent ranges; rectangles indicate 95% confidence limits; horizontal bars indicate means; and numerals above vertical bars show sample size.

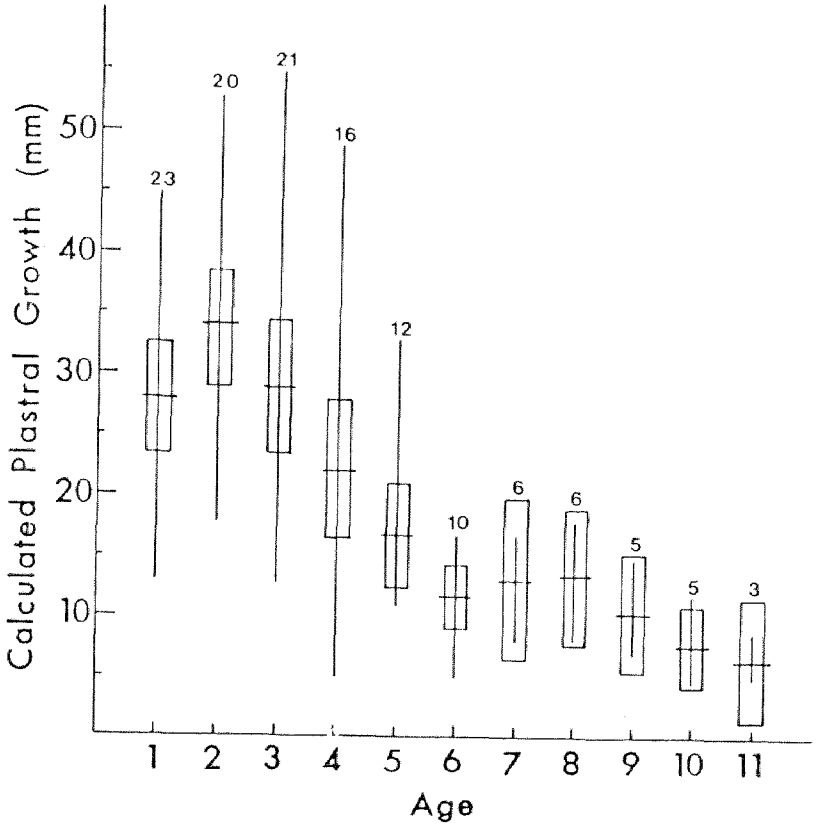

Fig. 7. Growth rates for Chelydra serpentina females calculated from carapacal annulae. Vertical bars represent ranges; rectangles indicate 95% confidence limits; horizontal bars indicate means; and numerals above vertical bars show sample size.

more because sufficient growth occurred to create clearly distinguishable annulae. Aging of females beyond 15 years was nearly impossible because while annulae were being produced, they were too close together to be reliably counted. Remarkably distinct annulae of two large males indicated ages of at least 35 years (Table 4). While three large females in our collection may be as old, they were considerably smaller than the males and counts of blending annulae indicated ages of only 15-20 years.

Plastral growth of males remained at about 30 mm/year until the fifth and sixth year when a slight decline occurred (Fig. 6). By year seven, growth rate had decreased to 17 mm/year and to less than 10 mm/year by year eight. The rate of decline then slowed gradually until by year 20 they grew at about 2.5 mm/year. Evidently, only a slight decrease in growth rates occurred while the males were maturing but an accelerated rate of decline was evident one or two years after maturity was obtained.

Plastral growth of females remained at about 30 mm/year through the third full year of growth (Fig. 7). It then declined at 6-7 mm/year until the sixth year, when the rate of decline slowed. A decline of 20% occurred in year nine and 25% in year ten with growth in year 11 of about 7 mm/year. This places the greatest decline in growth rates as follicular development (yolking) is beginning at plastral lengths of 123-150 mm (Table 5) and continues

through the period of oviduct enlargement (sub-adult). The second decline occurs about one year after most turtles are probably beginning nesting.

Two turtles recaptured within 15 days of one year of their first capture provide support for the above estimates. An eight year old 173 mm PL male added six mm in one year, very near the mean calculated growth rate for males of that size and well within the range for males of that age. A four year old 93 mm PL juvenile grew 26 mm in one year, just one mm above the mean for combined sexes seen at that size (Fig. 8) and midway between the means for males and females of that age (Figs. 6 and 7).

Growth of Chelydra serpentina is highly variable, especially in the first four or five years of growth (Figs. 6 and 7). Within these years the growth rate often varies by as much as 50 mm PL growth per year. Apparently within the onset of maturity this range of growth rates between individuals is no longer seen.

Habitat preference. Snapping turtles were found most often in association with obstructed or congested areas (Fig. 9). At Chichaqua with sufficient water present, traps were most successful when placed next to a beaver lodge (Fig. 10). This is illustrated in Fig. 11 by noting that the greatest number of snapping turtles were caught adjacent to a beaver lodge. Similar results were obtained with the transmitter-equipped turtles (Figs. 12 through 18) where

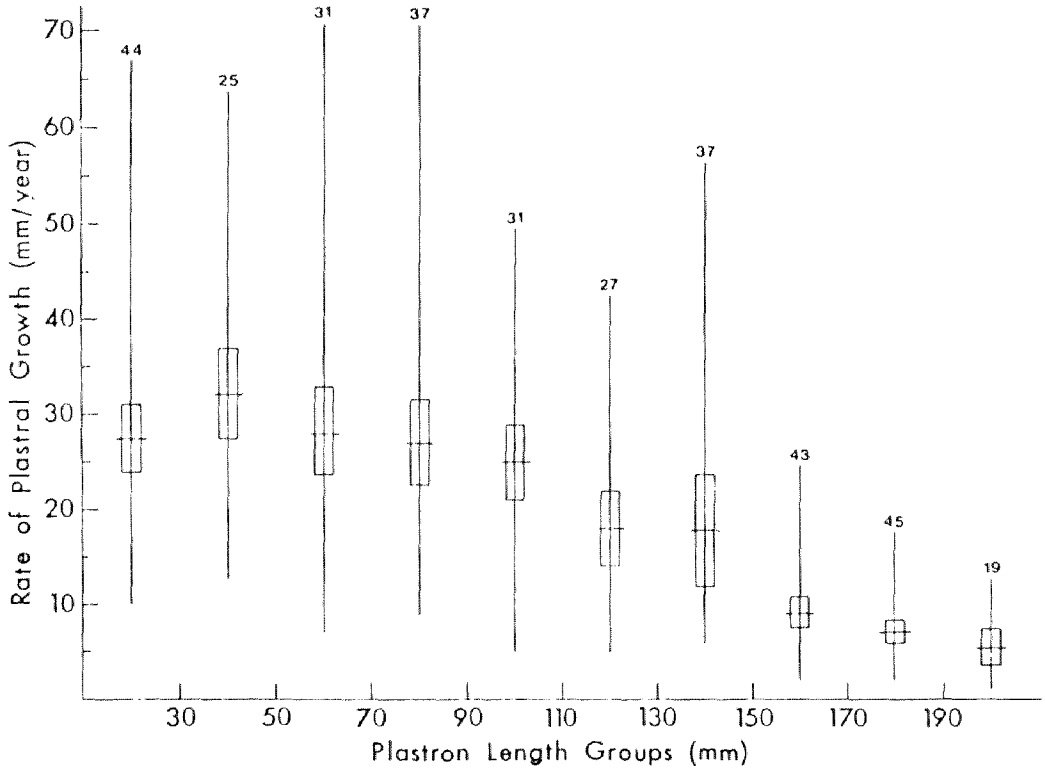

Fig. 8. Growth of combined sexes of Chelydra serpentina for different plastron length groups as calculated from carapacal annulae. The first group contains all turtles with measurable growth when plastral lengths were calculated <30 mm; the last includes growth calculations for turtles with plastra >190 mm. Vertical bars represent ranges; rectangles indicate 95% confidence limits; horizontal bars indicate means; and numerals above bars show sample size.

Fig. 9a. Typical refuge for snapping turtles.

Fig. 9b. Typical refuge for snapping turtles.

Fig. 10a. Active beaver lodge.

Fig. 10b. Active beaver lodge.

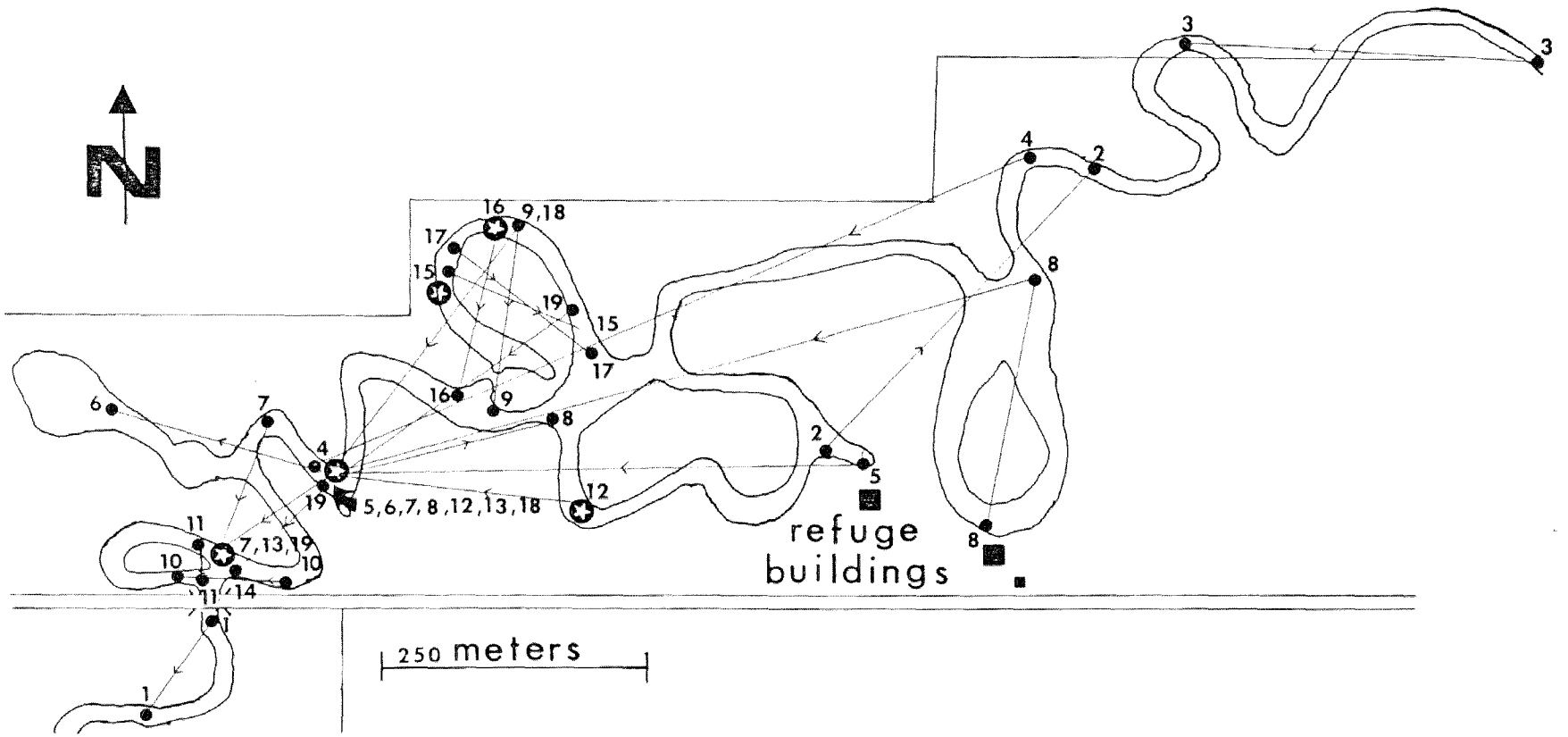

Fig. 11. Movement of recaptured Chelydra serpentina at Chichaqua Wildlife Area, 1976 - 1977
✪ = beaver lodge

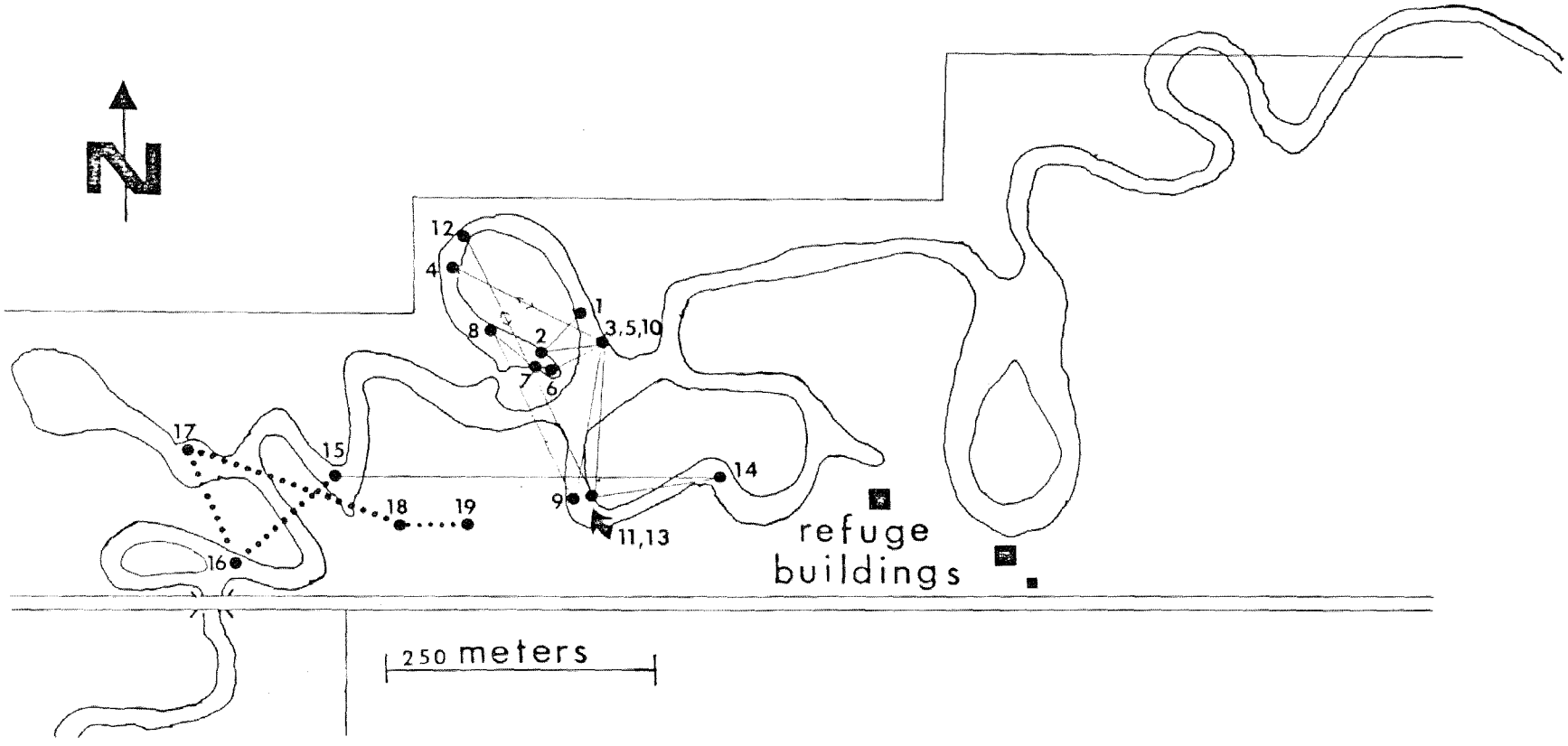

Fig. 12. Movement of transmitter-equipped Chelydra serpentina 1 (TT 1), 19 July - 6 Aug. 1976 and 1 July - 18 Sept. 1977.

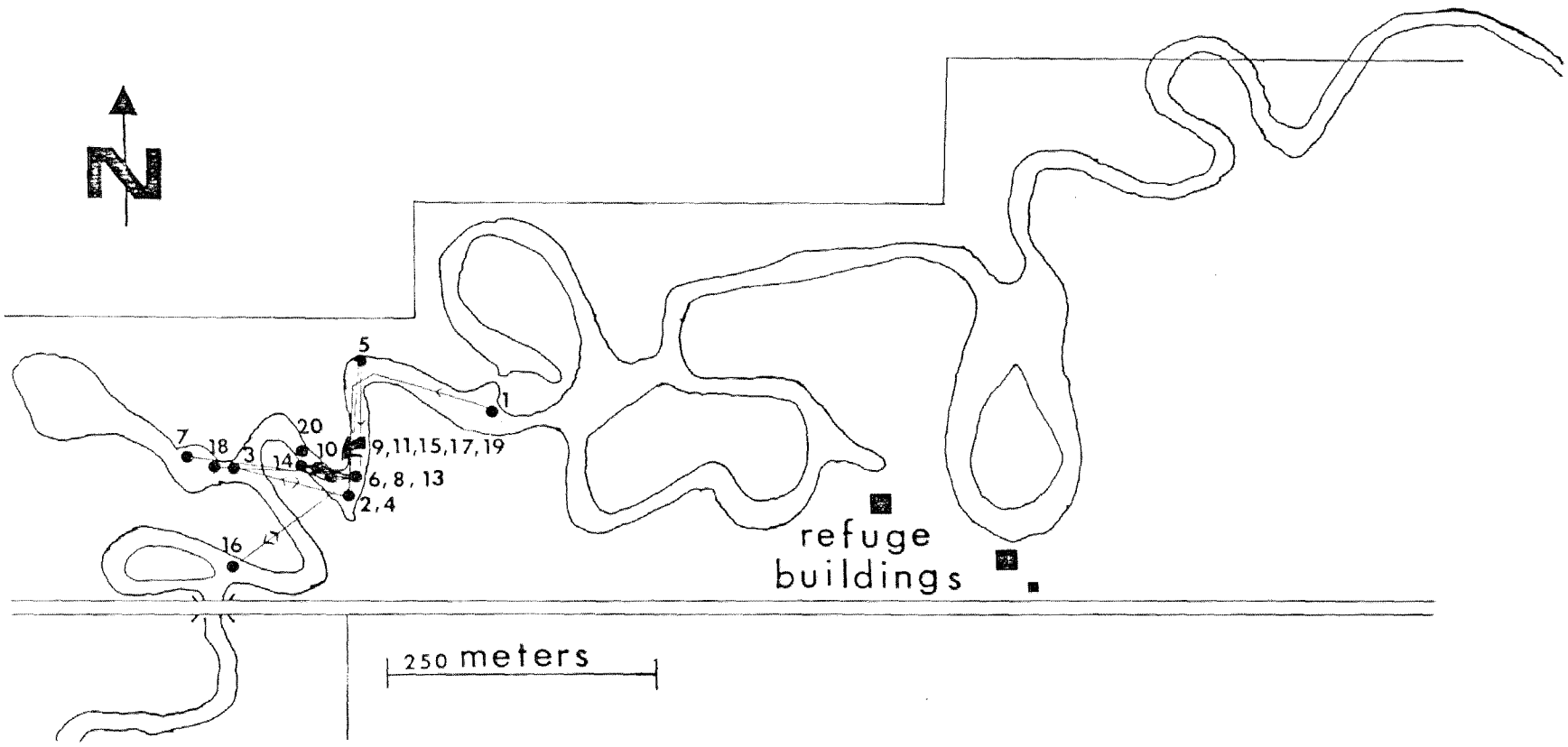

Fig. 13. Movement of transmitter-equipped Chelydra serpentina 2 (TT 2), 14 Aug. 1976 - 17 May 1977.

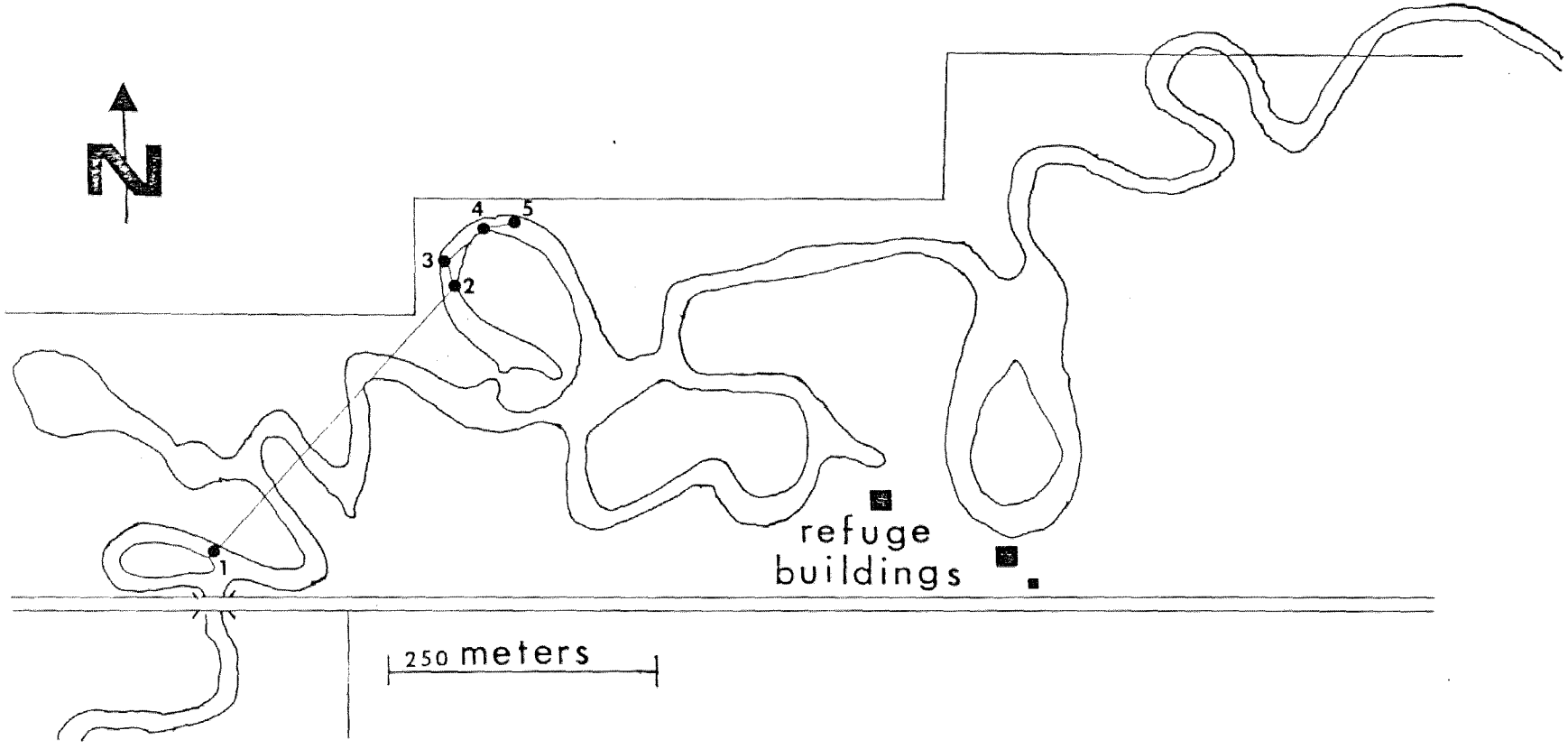

Fig. 14. Movement of transmitter-equipped Chelydra serpentina 3 (TT 3), 16 April - 27 May 1977.

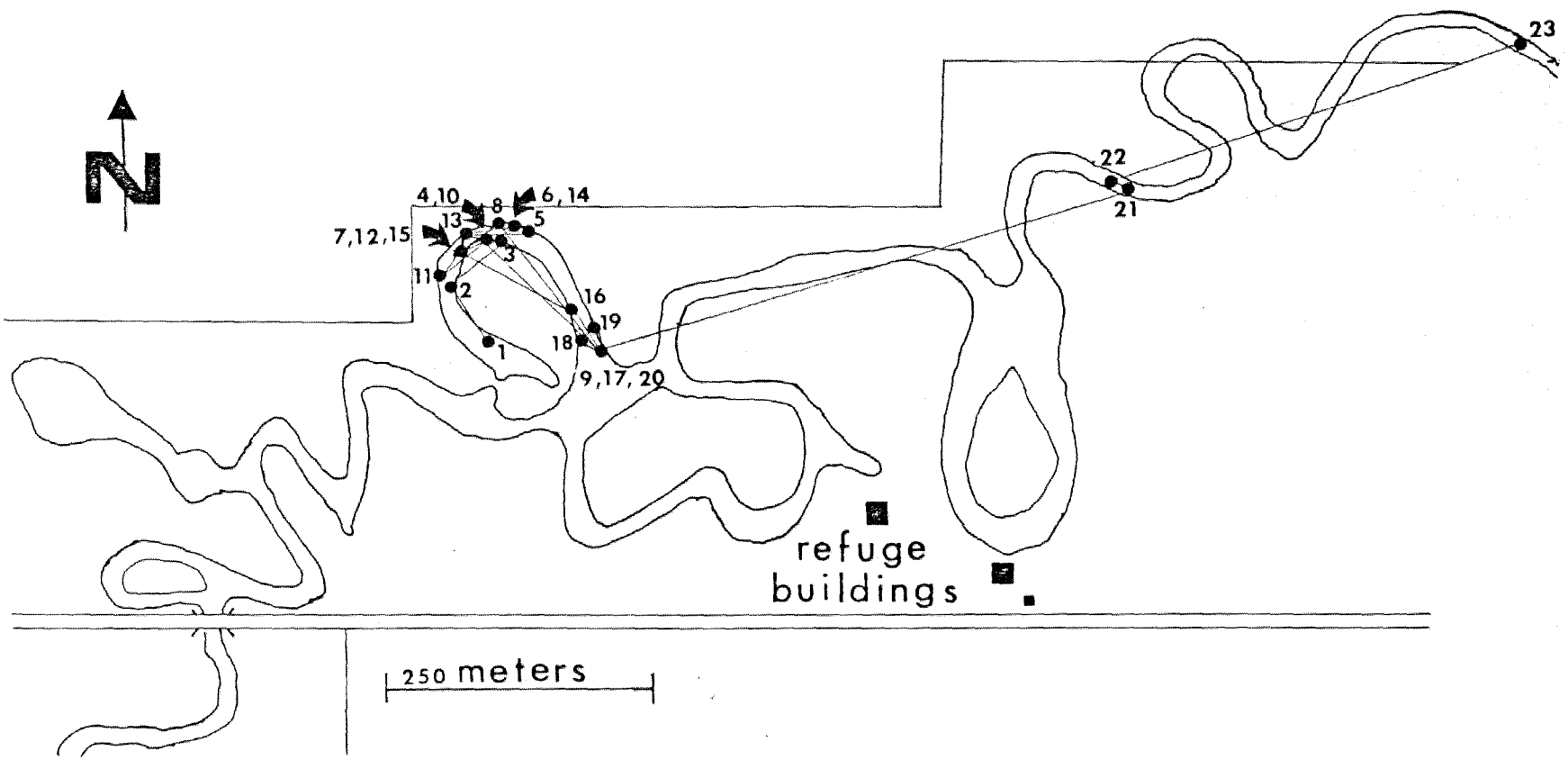

Fig. 15. Movement of transmitter-equipped Chelydra serpentina 4 (TT 4), 1 May - 6 Nov. 1977.

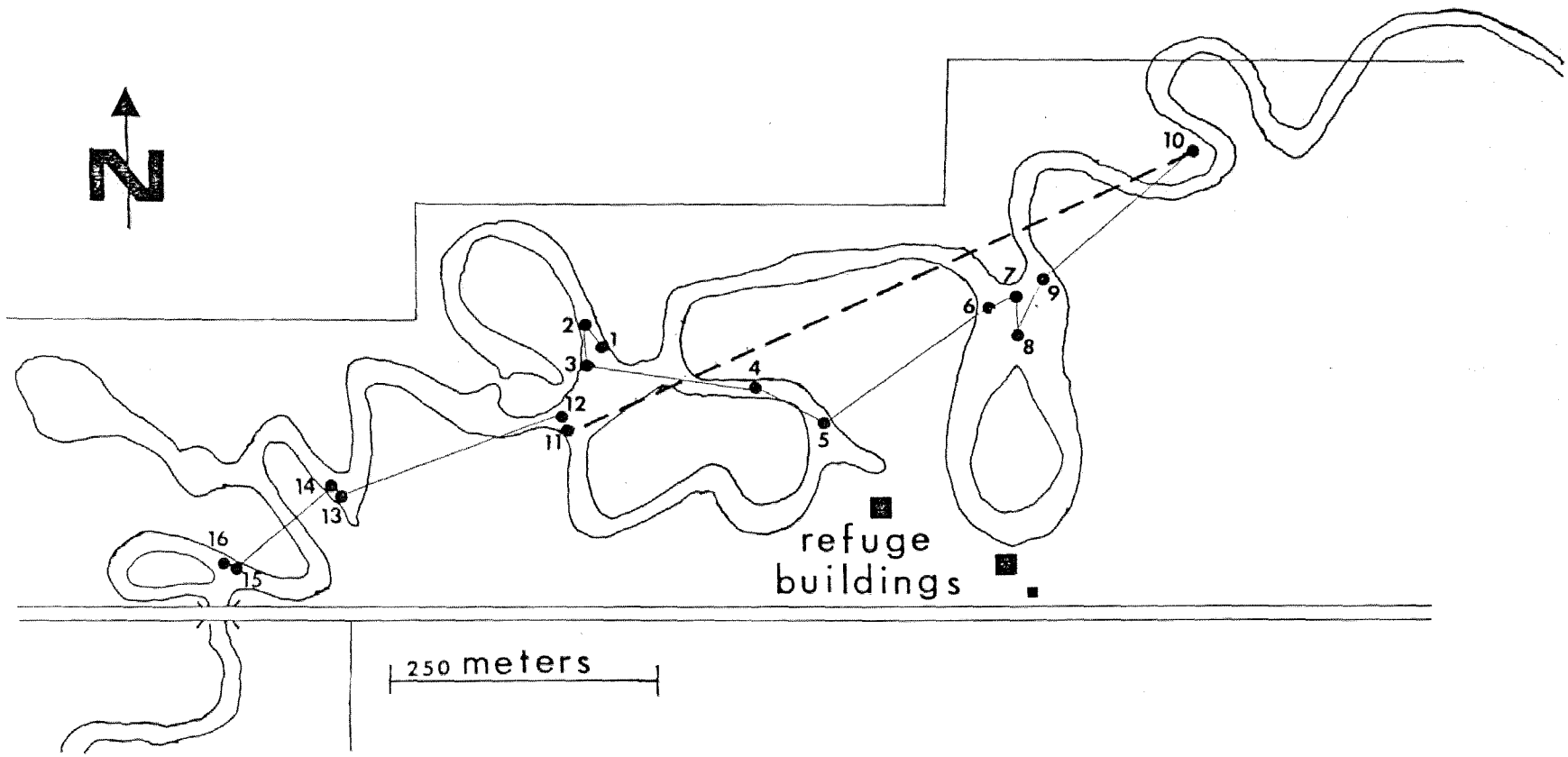

Fig. 16. Movement of transmitter-equipped Chelydra serpentina 5 (TT 5), 2 June - 9 Aug. 1977.

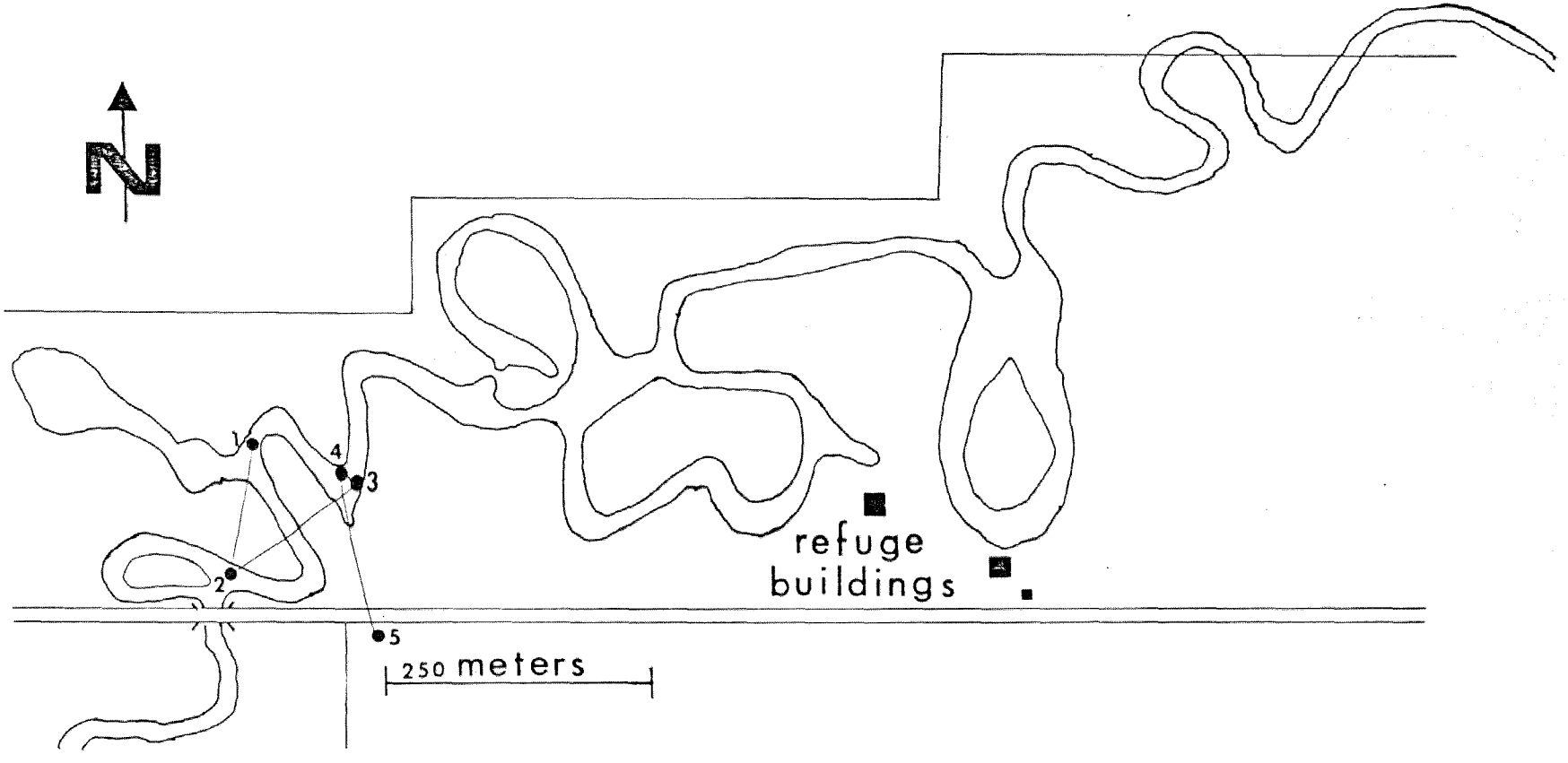

Fig. 17. Movement of transmitter-equipped Chelydra serpentina 6 (TT 6), 8 July - 9 Aug. 1977.

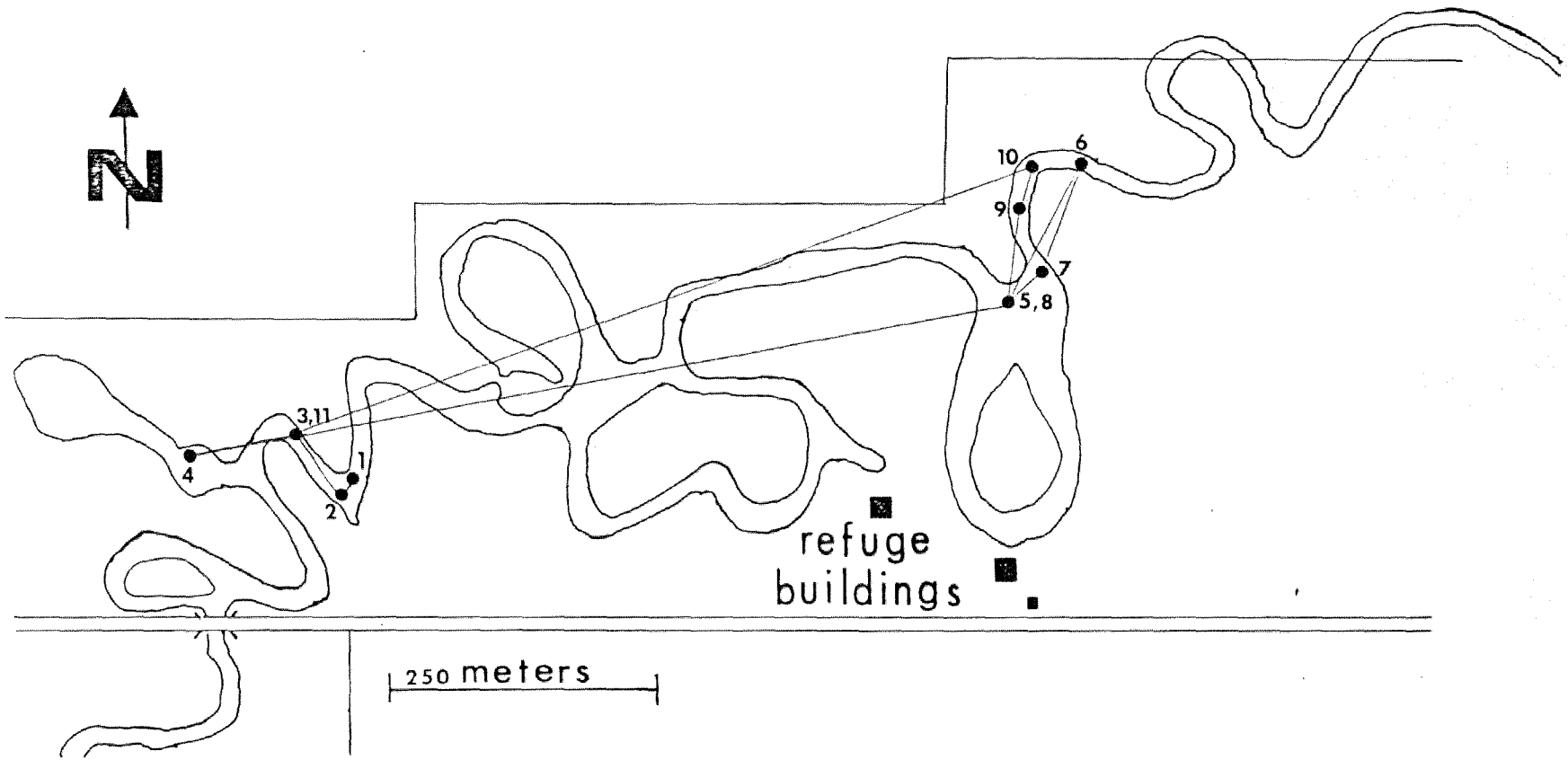

Fig. 18. Movement of transmitter-equipped Chelydra serpentina 7 (TT 7), 2 Aug - 24 Sept. 1977.

they were found most often in association with obstructed areas especially beaver lodges. Using TT 1 (Fig. 13) as an example, sites 1, 3, 4, 7, 8, 9, 11, 12, 15, and 16 are sites obstructed with brush, logs and other debris in the water. Sites 1, 3, 7, 8, 9, 15, and 16 are beaver lodges with sites 3, 11, and 16 depicted in Figs. 9b, 10a, and 10b respectively.

Snapping turtles also chose obstructed areas as hibernation sites. Two TTs (2 and 4) followed until activity ceased for the season selected congested sites, a beaver lodge and a pile of logs respectively. On one occasion 12 were taken during winter from under a single stump similar to the one in Fig. 9b, according to James Layton, area ranger.

With the marsh dry in summer 1977 (June 25 to August 10) snapping turtles often buried themselves about 11 cm in mud (Fig. 19a) or moved overland and burrowed in litter (Fig. 11b). All the TTs burrowed in mud in this manner at least once and three of five TTs followed at this time were found buried terrestrially at least once.

TTs found terrestrially were buried in litter. The depth seemed to depend on substrate texture. Forest litter was easier to excavate, being composed of leaves, sticks, and loose soil. TTs buried there were covered with up to 10 cm (average 5 cm) of litter. The one TT found in a prairie habitat was partially covered with the top of the

Fig. 19a. Transmitter-equipped turtle buried in mud, site disturbed by observer.

Fig. 19b. Transmitter-equipped turtle buried terrestrially.

carapace showing. TTs were buried in forest litter three of four times found terrestrially and once (Fig. 17, site 15) in a prairie area. Three of four sites were low areas representing old channels now filled with sediment. One site (Fig. 16, site 10) was an elevated area between two channels.

A difference was noted between spring 1977 mud burrows and those made later in the summer when the turtles were inactive for a week or more at a time. The more active spring turtles were covered by about 2 cm of bottom debris in 4-12 cm of water. Their partially extended heads were visible and their eyes open. Later in the season the TTs after moving would burrow at the edge of the water and did not move as the water receded. These turtles were an average 12 cm deep in mud with the anterior edge of the carapace 3 cm higher than the posterior. The head was partially extended with the eyes closed. When discovered, the buried turtles made no attempt to escape regardless of the way they were covered and were docile until removed from the mud.

For purposes of comparison, the criteria used by other authors for determination of maturity will be used here. Others have pooled at least some sub-adults and adults and classed them as adults. Live turtles were sexed on the basis of precloacal length but it was not possible to separate males from females among the smallest without

dissection. Those mature enough to be sexed with confidence are considered adult for the purposes of this discussion.

The traps used to capture snapping turtles have a limit as to the size of the turtle captured. While the largest turtle captured by hand equals the size of the largest trapped, it is conceivable that a few very large snapping turtles exist that would not be trapped. However, aging of the largest turtles trapped (greater than 300 mm CL) indicates ages of over 30 years and members of this group are uncommon forming less than 5% (6 of 127) of the turtles trapped. While it is believed that turtles of even larger size are very rare and represent a very small proportion of the population, the effect of these turtles on population estimates is unknown.

In Iowa snapping turtle populations, the data indicate approximately equal numbers of juveniles and adults. Of 64 snapping turtles captured at Chichaqua 37 of 64 (58%) were juvenile with 27 of 64 (42%) adult or sub-adult. Of turtles collected statewide and dissected 28 of 63 (44%) were juveniles and 35 of 63 (56%) were adult or sub-adult.

It appears that in Iowa, females are more frequent as juveniles but in mature snapping turtles, males become more frequent. Of the 27 adult and sub-adult turtles captured at Chichaqua 15 of 27 (56%) were male and 12 of 27 (44%) were females giving an adult and sub-adult male to female ratio 1:0.75. Of the females seven had plastral

lengths of 172 mm or greater and therefore were classed as adults and five had plastral lengths between 150 and 172 mm and were called sub-adult. All males above 150 mm PL were classed as adults. Sex could not be determined for juveniles without dissection. Of snapping turtles collected statewide and dissected (63), 25 were males and 38 were females thus a ratio including juveniles of 0.71:1. The juvenile male to female ratio was 1:6 (6 of 24). There were 35 adult and sub-adult individuals (56% of total), of which 21 were male and 14 were female. The male to female ratio for adult and sub-adults was 1:0.66. This compares with the 1:0.75 ratio for the adults and sub-adults at Chichaqua. Of the adults and sub-adults taken statewide, 60% were male and 40% female. These data indicate a substantial shift from a high proportion of females as juveniles to a dominance of males among more mature turtles.

Annual activity cycle. The earliest snapping turtle seen was a very large male observed sunning in the water on 9 March 1977. The water temperature was less than 13°C and the turtle being very sluggish, was caught by hand. Snappers first entered traps on 16 April 1977 and 31 August was the latest date they were trapped that year. In 1976 they were trapped as late as 7 September. On 18 September 1977 a large snapper was caught by hand as it rested on the bottom with its head partially extended in 1.1 m of < 13°C water. The last recorded movement of transmitter-equipped turtles

was 19 September 1977. This gives an activity period of 204 days. Since turtles did not feed aggressively enough to be attracted to baited traps until 16 April and the latest trapping record was 7 September, their feeding and estimated growing period appeared to be approximately 145 days.

The first four snapping turtles caught in 1977, 9 March to 1 May (59 days), were all male with PL of 271 mm, 209 mm, 151 mm, and 191 mm in order captured. All were adult with the possible exception of the third one listed. The first female was a sub-adult, 162 mm PL and was not taken until 11 May. It appears that males become active at least several weeks earlier than juveniles and females.

Snapping turtles were occasionally observed basking. The earliest observed was a very large male basking (sunning) in water on 9 March 1977. Possibly the same turtle was observed basking in water on 15 March and on land about 0.6 m from water on 27 March. When approached it moved quickly into the water. The only other time out of water basking was observed was 9 April 1977 when one was seen on a pile of limbs projecting about 12 cm above the water. After this date the few snapping turtles observed basking were in water and no basking was observed after 30 June.

Daily activity. Turtle activity was observed at all times of day with some preference for night time activity. If trapping success is assumed to be a function of activity,

then snapping turtles are apparently active at all times of day with some trend toward turtles entering traps more readily at night (1900-0600 hrs.). In 330 trap periods, 165 set during the day (0600-1900 hrs.) and 165 set during the night (1900-0600 hrs.), 27 snapping turtles were captured. Nine were taken during daylight and 18 at night. Chi-Square analysis ($X^2 = 2.99$, df = 1, .10 <p> .05) did not show this difference to be significant at the .05 level.

Observation of transmitter-equipped turtles supported the trend toward night time activity but the marsh becoming dry in summer 1977 hindered obtaining more complete data on this. The time of movement (day vs. night) was noted when possible. It could be noted in only 18 cases of which 5 of 18 (27.7%) occurred in the day and 13 of 18 (72.3%) occurred at night. Time of movement could not be determined for 75 movements.

The data suggest that snapping turtles are inactive most of the time. Of the 501 times TTs were located, they were actually observed moving only six times. This includes locations made while the marsh was dry and it should be noted that the turtles showed decreased activity at this time. Before the marsh was dry they were observed moving only 5 of 185 times turtles were located.

Response to dry marsh. Activity decreased when the marsh was dry. Only one TT was actually observed moving of 250 observations made of this and other turtles (TTs).

TT 4 (Table 6) did not move between 11 July and 25 August 1977 (44 days) and this was the longest period of warm weather inactivity recorded during the study. Other long periods of inactivity while the marsh was dry include 16, 10, 17, 8, 14, and 19 days. TT 2 apparently did not move for 10 days the previous year but the inaccuracy of the directional antenna used that year could easily have allowed it to move without being noticed. As described previously, these turtles (TTs) buried themselves in a different manner than snapping turtles that spring. Snapping turtles inactive for long periods burrowed either deeply in mud (Fig. 19a) or terrestrially (Fig. 19b). The transmitter-equipped turtles were significantly less active while the marsh was dry. Summation of the number of movements and total number of days the TTs were followed before the marsh was dry (1976 and 1977 until 25 June) and for the period the marsh was dry were as follows. Before the marsh was dry the TTs moved at least 56 times in 86 days (64.4% of the observations). While the marsh was dry, the TTs moved only 19 times in 128 days (14.8% of the observations). Four TTs were followed during parts of both periods. Chi-Square analysis of days moved vs. days in which no movement occurred give highly significant results in two cases (TT 1, $X^2 = 37.3$, $df = 1$, $p < .01$ and TT 4, $X^2 = 28.5$, $df = 1$, $p < .01$) and significant results in one case (TT 5, $X^2 = 4.2$, $df = 1$, $p < .05$). One case (TT 3, $X^2 = .95$, $df = 1$,

Table 6. Movements of transmitter-equipped Chelydra serpentina (TTs). Site number corresponds to those on Figs. 12-18 and dates represent period turtle was present at site.

TT 1, Adult male, followed 19 July to 6 August 1976 and 1 July to 9 September 1977.

Site No.	Date	to	Date	No. times found at site
1	19 July	--		1
2	20 "	--		1
3	21 "	--		2
4	22 "	--		1
5	24 "	26	July	2
6	27 "	--		1
7	28 "	--		1
8	29 "	--		1
9	30 "	--		1
10	1 Aug.	--		1
11	2 "	2	Aug.	2
12	4 "	--		1
13	5 "	--		1
14	7 "	--		1
15	6 Sept. 1976	--		1
16[a]	1 July 1977	--		1
17	11 "	27	July	33
18	1 Aug.	5	Aug.	11
19	8 "	18	"	33

[a]Dotted line on Fig. 16 represents movements in 1977.

Table 6. (continued)

TT 2, Sub-adult female, followed 14 August 1976 to 17 May 1977.

Site No.	Date	to	Date	No. times found at site
1	14 Aug.	--		1
2	14 "	--		1
3	14 "	--		1
4	14 "	--		1
5	15 "	--		1
6	15 "	26	Aug.	18
7	28 "	--		2
8	28 "	29	Aug.	4
9	31 "	--		2
10	2 Sept.	--		2
11	3 "	--		2
12	3 "	--		1
13	4 "	--		1
14	5 "	--		4
15	6 "	7	Sept.	5
16	15 "	--		1
17	21 "	23	Sept.	4
18	28 "	--		1
19	13 Oct.	2	Nov. 1976	15
20	17 May 1976	--		1

TT 3, Adult male, followed 16 April to 27 May 1977.

Site No.	Date	to	Date	No. of times found at site
1	16 April	--		1
2	29 "	2	May	8
3	8 May	21	"	16
4	24 May	25	"	6
5	26 "	27	"	4

Table 6. (continued)

TT 4, Adult male, followed 1 May to 6 November 1977.

Site No.	Date	to	Date	No. times found at site
1	1 May	--		1
2	2 "	10	May	7
3	11 "	12	"	3
4	16 "	20	"	6
5	21 "	--		1
6	24 "	--		1
7	24 "	--		1
8	24 "	--		2
9	25 "	--		1
10	25 "	--		5
11	26 "	--		3
12	27 "	--		2
13	31 "	--		1
14	1 June	1	June	2
15	1 "	3	"	8
16	13 "	--		2
17	14 "	1	July	15
18	7 July	--		2
19	11 "	--		1
20	11 "	25	August	61
21	29 August	--		1
22	30 "	2	September	5
23	11 September	6	November	16

Table 6. (continued)

TT 5, Adult female, followed 2 June to 7 August 1977.

Site No.	Date	to	Date	No. times found at site
1	2 June	--		1
2	2 "	--		1
3	3 "	--		3
4	13 "	--		2
5	14 "	--		2
6	25 "	1	July	9
7	7 July	--		2
8	8 "	--		2
9	9 "	--		2
10[b]	11 "	--		1
11	12 "	--		1
12	12 "	--		1
13	13 "	--		2
14	18 "	1	August	25
15	2 August	5	"	13
16	9 "	--		1

TT 6, Adult male, followed 8 July to 9 August 1977.

Site No.	Date	to	Date	No. times found at site
1	8 July	--		1
2	8 "	--		1
3	9 "	27	July	34
4	1 August	5	August	13
5	8 "	9	"	5

[b]This turtle was moved to site upstream (see text).

Table 6. (continued)

TT 7, Adult male, followed 2 August to 14 September 1977.

Site No.	Date	to	Date	No. times found at site
1	2 August	--		2
2	4 "	5	August	3
3	8 "	10	"	10
4	22 "	25	"	6
5	28 "	--		1
6	30 "	--		3
7	31 "	--		1
8	31 "	--		1
9	1 September	--		1
10	1 "	2	September	3
11	11 "	14	"	2

$p < .3$) was not significant at the .05 level. However, TT 3 was followed only the first four days of the dry marsh period before being lost.

If transmitter-equipped turtles moved while the marsh was dry, they preferred to do it during rainy periods. Fig. 20 compares snapping turtle movements to periods of rain. With the marsh dry (June 25 - August 10, 1977) there were four rainy periods lasting 1 to 5 days. During the first, 7 July, all four TTs moved. During the second rainy period of 16 July one of four TTs moved but at this time a large snapping turtle was observed moving south across N.E. 126 Ave. by James Layton, area ranger. After this precipitation several snapping turtle tracks were observed in the mud. The last two rainy periods were longer than one day, lasting 3 and 5 days respectively (Fig. 20). On both occasions 4 of 5 TTs moved at least once and after the first rain, fresh Chelydra tracks were again observed. At the end of the last rainy period two TTs moved and could not be relocated.

Cahn (1937) reported that during periods of drought, snapping turtles "move unerringly to a more habitable area." The Skunk River trapped (114 trap periods) between 17 July and 28 July yielded six snapping turtles none of which were marked. That some turtle species did not move into the river was indicated by the collection of two Blandings turtles, Emydoidia blandingi, normally a marsh turtle in a

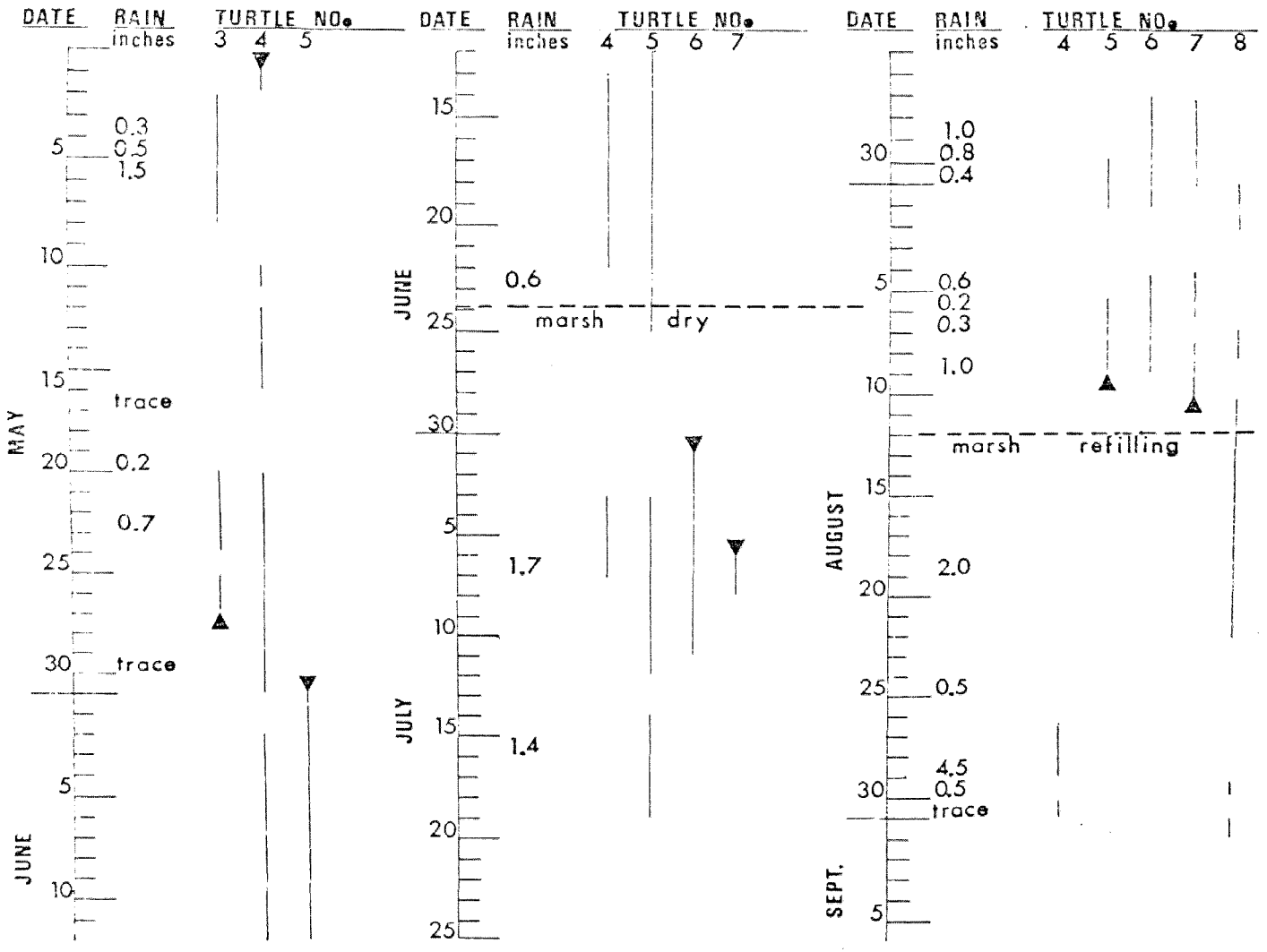

Fig. 20. Chelydra serpentina activity in relation to rainfall at Chichaqua Wildlife Area 1977. Vertical lines represent periods during which turtles moved at least once; ▼ = transmitter attached; ▲ = turtle lost.

deep pool of the river at this time. TT 5, which after release had moved 570 m downstream, was moved upstream (Fig. 16, sites 10-11) to see if it would continue its downstream movement. This turtle then moved upstream and buried itself in the mud.

Snapping turtles are capable of moving and traveling long distances in short times. Movements and time followed are described in Figs. 12-18 and Table 6. On Table 6, the period of time between the last date on any one line and the first on the next represents the period in which the TT moved. While distances measured are straight line, it seems unlikely the turtles followed this path. To do so, the snapping turtles would have had to scale earthen banks 1-3 m high. Between 1030 and 1130 hrs (1 hour) on 14 August 1977, TT 2 moved 250 m while monitored continually or 1/7 mph. This is the greatest speed recorded for a snapping turtle during the study (Fig. 13, sites 1-2). The greatest straight line distance moved was 833 m by TT 4 (Fig. 15, sites 20-23) between 25 August and 11 September 1977. TT 1 moved 510 m in two days and often moved 180 m a day while being followed in 1976 (Fig. 12). TT 8 moved 733 m in nine days. TT 7 moved 783 m in four days between 22 and 28 August and 730 m between 2 and 11 September 1977. Turtle #5 (Table 7) moved 520 m in five days.

Home ranges. Prior to the marsh drying, turtle movements were localized, suggesting home ranges (Figs.

Table 7. Date of captures and distance moved by recaptured *Chelydra serpentina* (turtle number corresponds to number on Fig. 20).

Turtle No.	Day/Month/Year	to Day/Month/Year	Distance Moved (m)
1	15/06/76	18/06/76	79
2	16/06/76	18/06/76	0
2	18/06/76	30/07/76	362
3	21/06/76	30/07/76	330
4	28/07/76	17/05/77	730
5	2/08/76	7/08/76	520
6	4/08/76	18/08/76	217
7	5/08/76	17/08/76	132
7	17/08/76	19/08/76	132
8	6/08/76	7/08/76	263
8	7/08/76	7/08/76	0
8	7/08/76	18/09/76	691
8	18/09/76	15/05/77	0
8	15/05/77	2/08/77	217
9	13/08/76	11/05/77	197
10	16/08/76	19/08/76	0
10	19/08/76	15/03/77	105
11	17/08/76	19/08/76	33
12	28/08/76	3/09/76	230
13	6/09/76	17/04/77	132
14	9/03/77	2/04/77	0
15	1/05/77	7/07/77	145
16	17/05/77	25/05/77	171
17	20/05/77	3/06/77	164
18	07/75	2/08/77	296
19	16/07/76	6/09/76	290
19	6/09/76	30/06/77	136

$\bar{x}$ = 206 m

12-18). Home ranges were calculated for turtles with five or more locations (Table 8). This included all the TTs and turtle #8 (Table 8) captured six times. While the marsh was dry and as the marsh was refilling, the turtles moved longer distances thus increasing the range. Home ranges are calculated on basis of total number of locations and on number of locations recorded before the marsh was dry. The average home range was 2.99 ha based on total number of locations and 1.33 ha based on locations before the marsh was dry.

Snapping turtles repeatedly returned to a location "homesite" after foraging and this was especially true before the marsh was dry. TTs 1 and 2 illustrate this. TT 1 returned three times to a beaver lodge (Fig. 13, site 3: Fig. 10a) and two times to another beaver lodge after foraging (Fig. 12, site 11). TT 2 returned five times to an active beaver lodge and three times to an inactive one, five m east of the active one, after foraging.

The data suggest that home ranges are somewhat temporary, perhaps lasting a season and may occasionally change within a season. Turtles tended to make long distance movements early in the spring or late in the season and then remain in the area during the summer. TT 1 moved 380 m between 7 August and 6 September 1977. TT 3 moved 350 m between 16 and 29 April 1977. TT 4 moved 833 m between 25 August and 11 September 1977. TT 7 moved 783 m

Table 8. Home ranges of Chelydra serpentina with five or more locations before and while marsh was dry (includes all transmitter-equipped and turtle 8 captured six times).

Turtle number	Carapace length (mm)	Plastron length (mm)	Total number of locations	Total range (m^2)	Number of relocations before marsh was dry	Range before marsh was dry (m^2)
TT 1	216	173	100	32,500	16	13,300
TT 2	200	161	62	13,300	62	13,300
TT 3	271	209	35	19,000	35	19,000
TT 4	253	191	140	32,500	61	8,000
TT 5	229	176	70	31,500	9	6,500
TT 6	311	242	54	8,300	0	--
TT 7	300	220	35	26,250	0	--
# 8	126	100	6	20,000	5	20,000
				$\bar{X}$ = 22,919 m^2 (2.29 ha)		$\bar{X}$ = 13,350 m^2 (1.33 ha)

between 22 and 28 August 1977 and 730 m between 2 and 11 September 1977. Turtle #4 (Table 7) moved 730 m between 28 July 1976 and 17 May 1977. Turtle 8 moved 691 m between 7 August and 18 September 1976. Turtle 5 moved 520 m between 2 and 7 August 1976. The great majority of long distance movements occurred in fall or spring, suggesting home ranges are maintained during one season but can change from one year to the next. Snapping turtles may occasionally change home ranges within one season. TT 7 (Fig. 18) appears to have shifted home range during the summer.

In general, the longer the time between recaptures the greater the distance moved. Nineteen snapping turtles were recaptured 27 times in 1976 and 1977. Movements and dates of capture are described in Fig. 12 and Table 7. One turtle (8) was captured six times, twice in one day by fishermen with no movement recorded. The greatest distance moved was 730 m by turtle 4 between 28 July 1976 and 17 May 1977.

It appears snapping turtles have large overlapping home ranges implying that home ranges are not rigorously defended. If they were rigorously defended, the area north of N. E. 126 Ave. would support only six snapping turtles. This figure is derived by dividing the available habitat area north of N. E. 126 Ave. (8 ha) by the average home range (1.33 ha) of snapping turtles. However, 44 snapping turtles were captured in this area in 1976. Also TTs were

observed to move past one another in several instances, for example TTs 3 and 4 (Figs. 14 and 15).

Homing ability. Snapping turtles apparently have some homing ability or ability to recognize their surroundings. This is illustrated by TT 7. After leaving from under a stump (Fig. 18, site 3) on 8 August 1977, this turtle moved 740 m east to site six. On 1 September 1977 it was relocated under the stump at site 3 in Fig. 18. As stated previously, TTs repeatedly returned to a location after foraging.

Population density estimates. In 1976 44 snapping turtles were marked in the study area north of N. E. 126 Ave., comprising eight hectares. This area contains approximately 4000 m of channel, 20 m wide, giving a total surface area of eight ha. Of the 25 snappers examined in 1977, eight were marked previously. Application of the Lincoln Index leads to a population estimate of 137.5 snapping turtles for the area north of the road. This gives a density estimate of 17.2 (17) snapping turtles per hectare. Determination of 95% confidence gives 107 to 163 turtles or a possible density range of 13.4-20.4 turtles per hectare. Assuming that the area north of N. E. 126 Ave. represents approximately 1/3 of total suitable habitat, the total population estimate for Chichaqua Wildlife Area is 412 snapping turtles.

DISCUSSION

Growth and maturity. It appears that male snapping turtles from Iowa begin to mature at about 135 mm PL, 191 mm CL, and in their fourth full year of growth. By the end of their fifth nearly all Iowa males were mature. White and Murphy (1973) found testicular sperm in Tennessee Chelydra at 145 mm PL, approximately the same size and presumably about the same age as maturing Iowa male turtles. Mosiman and Bider (1960) found the smallest testicular sperm bearing Quebec specimen to have a carapace length of 210 mm. A comparison with Table 4 of the present study would place the age of that turtle at four to five years and about the same plastral length as maturing Iowa turtles, assuming growth rates and shell proportions are about the same. These studies indicate almost no difference in size at maturity of males among three widely latitudinally separated localities.

It appears that females do not rapidly mature but undergo a period of sub-adult development. During this sub-adult phase (ages 4-7), follicles may enlarge considerably but are not ovulated. While an uncommon fast growing individual may be mature in its sixth year, most do not ovulate until their seventh or eighth year and larger than 162 mm PL and 229 mm CL.

Mosiman and Bider (1960) found immature female turtles as large as 219 mm CL with follicles up to 16.8 mm

in diameter, but concluded that females like males mature at around 200 mm CL. They did not mention corpora lutea and the two of their turtles with evidence of ovulation had oviducal eggs and were 276 mm CL or larger. It is suggested that their data do not conflict with an average size at maturity for females of approximately 222 mm CL with most individuals maturing at an even larger size as appears to occur in Iowa. It appears that female snapping turtles have a period of sub-adult existence in which the follicles may enlarge considerably but are not ovulated and if so Mosiman and Bider (1960) probably listed sub-adult females as adults.

White and Murphy (1973) utilized ovarian follicles of 4.4 mm diameter or larger as their criterion for maturity after Cagle (1944a). On this basis they concluded that females mature at about 145 mm PL, which would be equal in our population to about 200-210 mm CL and 5 to 6 years. The present study demonstrates follicles as large as 6.5 mm in turtles that had not ovulated and would not have had time to ovulate during that year. Adding one or two years of sub-adult existence would make the size for maturity of their females equal to those from Iowa.

The data show an association between periods of rapid growth rate decline and state of reproductive maturity. Plastral growth of males remained at about 300 mm/year until the fifth and sixth year when a slight decline

occurred (Fig. 6). Nearly all males are mature by the end of the fifth year. By year seven growth rate had decreased to 17 mm/year and to less than 10 mm/year by year eight. If growth rate were to be influenced by an adult complement of androgens, the full effect on growth would not be evident until measurements taken one or two years later.

The association in females of growth rate decline and state of reproductive maturity is less apparent due to the period of sub-adult existence (years 4-7). Females experienced a decline of 6-7 mm/year in years 4-6. This places the greatest decline in growth rates as follicular development (yolking) is beginning. A decline of 25% occurred in year nine and 25% in year 10 with growth rate in year 11 of about seven mm/year. This second decline occurs about one year after most turtles are probably beginning to nest.

Snapping turtles apparently undergo a decreased growth rate when reproductive maturity is achieved. In males the decline is sudden and follows maturation about one year but in females it is most severe in the 3-4 years of sub-adult life as yolking and follicular enlargement are taking place and again declines shortly after full maturity.

When data for males and females are combined and correlated with plastral lengths (Fig. 8), a blending effect occurs during the first six size intervals, giving the gradual decline reported by others. However, a small but

noticeable decline occurs in the 150-170 mm PL size class; the size at which most Chelydra are mature. Gibbons (1968b) examined six specimens of both sexes from a polluted river in Michigan. He concluded that growth declines each year after the first but there was no evidence that the growth rate slows more rapidly once maturity is reached. Graham and Perkins (1976) studied the growth of snapping turtles in a polluted marsh in Massachusetts. Using eight specimens they found that growth generally declines each year through the sixth but then an increase occurred which they attributed to a shift in diet. The previous two studies were limited by small sample sizes that could not compensate for the great variability found in growth rates and by the fact that the two sexes were combined resulting in a blending effect.

It was usually possible to estimate the age of male turtles to 20 years or more because sufficient growth occurred to create clearly distinguishable annulae. Aging of females beyond 15 years was nearly impossible because while annulae were produced, they were too close together to be reliably counted. Perhaps this could be explained in part by the high energy demands on females for nesting and egg production, assuming an equal probability of finding food by both sexes. Neither Froese (1974) or the present study obtained much data on the activity of adult females. It would be interesting to see if adult females are more

active than males because of this increased need for energy. However, for many other reptilian species, females are as large or larger than males.

It appears that growth is greater and more variable in juvenile snapping turtles but that once maturity is reached growth and variability are reduced (Figs. 6, 7, and 8). Froese (1974) found that small males are significantly more active than large ones. It is conjectured that in young snapping turtles growth is controlled more by environmental factors (food availability) than by activity (food searching) with large adult growth rate being controlled more by activity (food searching) and not to such a large degree by food availability, assuming they can find food if they search for it.

In recent years commercial turtle trappers have indicated that snapping turtle population has decreased significantly over the years. Destruction of many nesting areas and straightening of many rivers has probably been a major reason for this decline. However, in view of the fact snapping turtles are ubiquitous animals, capable of doing quite well in polluted environments and in small farm ponds it is possible that a significant part of this decline is the result of trapping by man. Turtles as a group are relatively slow growing and take many years to mature. While snapping turtles are among the faster growing turtles, females still take 7 to 8 years to become reproductively

mature. This is several years after they are large enough to have market value. Because of this many females are removed before reproductive maturity is reached, thus greatly reducing the reproductive capacity of a population. Although it is doubtful that Chelydra will be extirpated over large parts of their range, it is suggested that some thought be given to increasing minimum legal size (i.e., through net size) in light of the decreasing numbers of large adults in recent years.

Habitat preference. The literature suggests that Chelydra serpentina prefer congested areas to open ones (Froese, 1974). Pope (1939) found snapping turtles under submerged logs and Lagler (1943) found them in association with logs and stumps. This study supported these observations. At Chichaqua, snappers were often captured in and around congested areas, especially beaver lodges. The study area had a very high population of beavers and thus a large number of lodges, both active and abandoned. These beaver lodges presented ideal habitat with many branches of various sizes mixed with mud. Before the marsh was dry the TTs were found in congested areas about 75% of the time, supporting the trapping data.

Hibernating snapping turtles were also found in association with congested areas as has been observed by others. Clark and Southall (1920) stated Chelydra serpentina hibernated in muskrat lodges and under fallen

logs. This preference for beaver lodges seems to indicate a commensal relationship as was observed by Ernst (1976) with spotted turtles, Clemmys guttata and muskrat (Ondata zibethica). Many Chichaqua snappers used the lodges as the center of their home ranges, returning to them after foraging. The lodges were used as winter hibernaculae and presumably as retreats from danger. Froese (1974) found that snapping turtles when disturbed would return quickly to their homesites. Beavers apparently showed little reaction to the presence of snapping turtles, as none of the snappers examined at Chichaqua showed teeth marks as would be expected if the beavers gnawed on the turtles.

Population structure. At Chichaqua and statewide there were approximately equal numbers of juveniles and adults, with 58% and 44% juvenile respectively. Froese (1974) found a similar situation in Tennessee with 57% being juvenile. Mosiman and Bider (1960) found 51% of the snapping turtles in a Canadian population juvenile. Major (1975) found more adults than juveniles but he used commercial traps which would allow the smaller juveniles to escape. Thus it appears that in many locations the number of juveniles equals or exceeds the number of adults. The high number of juveniles in the population possibly indicates some adult mortality. The fact that adult snapping turtles are used for food by man would decrease the number of adults in a population.

It appears that as Iowa snapping turtles mature the sex ratio changes from females being more frequent as juveniles to males predominating as adults. Sexton (1959) found a similar situation in a population of Chrysemys picta, finding in painted turtles of known sex a male to female ratio of 1:1.45 but a ratio of 1:0.76 among mature individuals, indicating a change in sex ratios as the turtles mature. Froese and Burghardt (1975) found mature male snapping turtles more frequent than mature females (1:0.65 ratio) in a Tennessee population and Hammer (1972) found female mortality higher than male. However, several studies indicate this phenomenon is not found in all snapping turtle populations. Mosiman and Bider (1960) using 55 specimens, obtained over a three-month period from a Quebec population, indicated no shift in sex ratios. The sex ratio was essentially 1:1 in both groups. White and Murphy (1973) found in a Tennessee population (turtles collected April to November) a ratio of essentially 1:1 (25 males to 28 females) while the corresponding ratio in Iowa snapping turtles was 0.71:1. Major (1975) using 49 adult specimens obtained over a six-month period found a male to female ratio of 1:1.3 among mature turtles. Thus the literature concerning this phenomenon appears contradictory. Any conclusion at this time would be premature and until further studies are done there seems little implication seen in the shift of sex ratios as Iowa snapping turtles mature.

Annual activity cycle. It appears that Chichaqua snapping turtles have an activity period of 204 days and a feeding and estimated growing period of 145 days. Snapping turtles have been reported moving under ice: Finneran (1948) in Connecticut and Gentry (1956) in Tennessee. This is rare however, as in water below 13°C snappers move very sluggishly if at all. On the two occasions snapping turtles were captured in water under 13°C they seemed unable to move until warmed.

In comparison to Chelydra activity, Chrysemys picta movement was first observed 9 March and last on 2 November giving as activity period of 239 days, 35 more than that observed for snapping turtles. Chrysemys picta first entered traps on 16 March and last on 2 November providing a feeding and estimated growing period of 232 days, 87 more than observed for snappers. Thus it seems that snapping turtles have a shorter activity and feeding period than the other common turtle at Chichaqua.

It is interesting to note that the four snapping turtles caught during the first 59 days of activity in 1977 were all male. All were adult with the possible exception of one, 151 mm PL. It is quite possible that this male was mature since another male of 149 mm PL taken from the area for the maturity study was mature (Table 4). It thus appears that adult males may become active at least several weeks before juveniles and adult females. Gibbons (1968a) found

a similar phenomenon with Chrysemys picta studied in Michigan where adults became active several weeks before juveniles and indicated if hunger were the motivation, juveniles having a higher metabolic rate should be the first to appear not the last. He stated, "males unable to operate at low temperatures (providing such behavior is genetic) would be ultimately eliminated from the population, since those appearing early would have a greater chance of mating with an unfertilized female (disregarding sperm retention)." It is possible that this occurs with snapping turtles but the small number captured makes this conclusion tentative at best.

Snapping turtles were observed basking out of water only in the spring (27 March and 9 April 1977). After the latter date, the few observed basking were doing so by laying motionless at the water's surface. None were observed basking after June. Ewert (1976) found with one exception (2 September) all aerial basking of snapping turtles took place before 18 June. Ewert (1976) noted that the 2 September example, "occurred after a spell of cool overcast weather." Cooper (1975) and Mahmoud (1969) found that Kinosternon flavescens exhibited a photophobic tendency that became more pronounced as summer progressed. This appears to be the case with snapping turtles, with aerial basking confined to spring when the water is cool. The lack of aerial basking and basking in general as summer progresses

may result from increasing water temperatures and reduced need for thermoregulative basking.

The presence of whole Chelydra eggs on 25 and 27 May 1977 in 0.7 m of water is difficult to explain. Turtle eggs are normally deposited above the water line. The eggs were fresh and well-formed with a shell of normal thickness, thus ovulation and shell deposition probably functioned normally. It is conjectured that the mechanism responsible for egg laying (ovapositioning) malfunctioned although I have no proof of this. Twenty-five May is the earliest date at this latitude for fresh snapping turtle eggs being found. Kezer (1937) recorded finding eggs on 31 May in New Jersey. In the present case the particular date must be viewed with caution as the eggs were found in a highly abnormal location.

Daily activity. Trapping data indicate that snapping turtles show some trend for night time activity (1900-0600 hrs) but the difference between day and night activity was not significant at the .05 level although the evidence was suggestive ($p = < .10$). Froese (1974) divided the 24 hour day into four equal time periods; morning (0400-1000 hrs), day (1000-1600 hrs), evening (1600-2200 hrs), and night (2200-0400 hrs). The percentages caught in the respective time period were 16%, 29%, 44%, and 11%. While the activity was greatest in the evening (1600-2200 hrs) with 44% of the turtles being captured in that period the difference was not statistically significant ($X^2 = 4.6$, df = 3,

$p > .05$). It appears that while snapping turtles can be trapped at all hours, there is a strong trend toward evening or night time activity, as reflected by increased trapping success at that time.

Several assumptions are made in inferring that trapping data reflects activity. It is assumed that snapping turtles are equally likely to enter traps during light or dark hours (i.e., they do not react adversely to seeing the trap during the daylight hours), and most turtle activity is related to feeding. TTs 1 and 2 were observed to move past freshly baited traps without being captured on 22 July and 2 August 1977 respectively. In light of these assumptions, the trapping data should be viewed with some caution if it alone is used to measure activity.

TTs also showed a trend toward night time activity but the decline in activity associated with the drying of the marsh in 1977 interfered with the gathering of normal activity data in the present study. Of 18 movements in which time could be noted, 5/18 (27.7%) occurred in daylight hours (0600-1990 hrs) and 13/18 (72.3%) occurred at night (1900-0600 hrs). Froese (1974) found the greatest turtle activity occurred at night and the least at midday. A combined analysis of his 11 transmitter-equipped snapping turtles indicated significant differences if activity rates across four equal time blocks; morning, day, evening, and night ($X^2 = 9.74$, $df = 3$, $p = < .05$). Murphy and Sharber

(1973) relocated three radio-equipped snappers 600 times between July and November and reported no nocturnal vs. diurnal differences in activity. However, they did not state their methods in determining activity, they had a small sample size, and snapping turtles are beginning to hibernate in late September. In view of the evidence (trapping success and transmitter-equipped turtle data) it appears that adult snapping turtles are active at all times of the day but show a preference for night activity. This supports earlier anecdotal accounts of nocturnal activity by Pope (1939), Brown (1969), and Ernst and Barbour (1972). It would be interesting to see the effect of season (spring, summer, and fall), juvenile vs. adult, and sex of turtle on activity. In both the present study and that of Froese (1974), males were mainly used.

Snapping turtles are inactive most of the time as indicated by the data. The activity of snappers appears to be concentrated into short periods of time. In the present study, TTs were actually observed moving only a few times. Froese (1974) found a similar situation in which snapping turtles were found at their homesites 74% of their total locations. It appears that adults have short periods of activity separated by periods of inactivity. Baldwin (1926) reported the cessation of activity of Chelydra and Chrysemys following food ingestion. Wood (1953) reported similar findings in young Chelydra. It is possible that

snappers alternate brief periods of feeding and activity with periods of inactivity. However, activity may or may not be highly correlated with feeding. Snapping turtles may move for a variety of reasons, to lay eggs, mating drive, or possibly as Cahn (1937) stated "wanderlust."

Response to dry marsh. During the summer 1977 snapping turtles were found burrowed deep in mud or terrestrially for as long as 44 days. It appears that snapping turtles exhibit the following behavior when the habitat dries up. They burrow deeply in mud in most cases and occasionally burrow terrestrially. When buried terrestrially, they prefer low shaded locations where conditions are more favorable. They remain buried until conditions improve, such as a significant rain or refilling of the habitat. If they do move while their habitat is dry, they prefer to do it during rainy periods when conditions of low humidity and high temperature would be less extreme.

Turtles can respond to severe drought in various ways. They can remain in the shrinking pools as some Chrysemys and Pseudemys apparently do (Cahn, 1937; Christiansen, personal communication). They can migrate randomly in hopes of finding a new water source as some Chrysemys and Pseudemys do (Cagle, 1944b). They can burrow in the mud as most Chelydra do (Cagle, 1944b and present study) or they can move terrestrially and bury as kinosternid turtles (Mahmoud, 1969; Cooper, 1975) and some snapping turtles do.

Kinosternids are adapted to temporary pools in a xeric environment and aestivate each summer whether their pools dry up or not. Cooper (1975) studying a population of Kinosternon flavescen spoonerii in Iowa stated that "Illinois Mud turtles apparently aestivate during the hottest part of the summer and remain inactive until spring." He indicated that this behavior in Iowa (not a xeric state) is probably a reflection of the turtle's xeric adapted history. Mahmoud (1969) reported that the Oklahoma Mud turtle, K. f. flavescens, aestivates terrestrially during the serotinal part of the summer, when the temporary pools these turtles inhabit are usually dry and is only occasionally active in the fall.

Snapping turtles are not xeric adapted turtles and do not aestivate yearly as kinosternid turtles do. Hutchison et al. (1966) found the maximal temperature tolerance of snapping turtles to be one of the lowest they examined (39.46°C) and Ernst (1968a) reported a high water-loss gradient for snappers, hardly expected traits of a desert adapted turtle. That Chelydra do not aestivate yearly is shown by the fact that at the corresponding time the previous year, even though the water level was low, snapping turtles were still entering traps. Two TTs followed at that time (Summer 1976) were active and did not burrow in the manner stated.

As stated previously, snapping turtles have a low

thermal maximal temperature and a high water-loss gradient, and it appears that they reduce mortality, during periods when the habitat dries up, by burrowing either deeply on mud or terrestrially. While buried yet able to breathe, snapping turtles would be subjected to less extremes of heat than would be the case if they remained in the shallow shrinking pools. Three of four terrestrial sites were low spots and three of four were shaded forest thus having more moisture and lower temperatures than higher and more exposed sites.

Cagle (1944b) observed the behavior of turtles in Michigan when several lakes in the region dried and described their response. He noted that, "twelve large specimens of Chelydra were buried at a depth equal to the lengths of their necks . . . The repeated movement of the head to the surface had kept open a tube." He also noted that generally Chrysemys and Pseudemys either clustered in the remaining pools or attempted to migrate randomly out of the area. Chelydra were not observed to do this. Cagle (1944b) reported a statement by commercial turtle trappers that snappers would remain in the dry lake bed until cracks reached the turtles or conditions improved. It seems likely that in periods when the habitat dries up, Chelydra serpentina burrow in the mud and remain there until conditions improve or sufficient rain elevates humidity and permits a search for better habitat. This was indicated by movements of TTs

when it rained while the marsh was dry and the marsh briefly had a few cm of water (Fig. 4b). Gibbons (1970) found that terrestrial movements of aquatic turtles followed periods of rain but the habitat was not dry during his study. He did not mention a particular species of turtle in connection with this rainy period movement but the population was composed primarily of Pseudemys scripta, P. floridana, Kinosternon subrubrum and Sternotherus odoratus with Chelydra making up less than one percent of the total. During periods of rain the temperature is lower, thus the turtles presumably would be in less danger of overheating and desiccation than if they moved when the environment was dry and warm. This preference for moving in rainy periods probably reduces mortality due to the causes just stated. The general decrease in activity during the drought undoubtedly reflects the turtles attempts to avoid desiccation and overheating by remaining underground until rain lowers the temperature and increases the humidity.

It has been reported that during a period of drought, snapping turtles move unerringly to a more congenial habitat (Cahn, 1937). Cagle (1944b) found snapping turtles respond to drying of habitat by burrowing in mud. The present study supports Cagle (1944b). The TTs followed at the time the marsh was dry did burrow in the manner described by Cagle. The Skunk River was trapped at this time to see if marked turtles had moved into it and none

of the six snappers captured were marked. During this period, one TT which had moved downstream was relocated upstream to see if it would continue its movement downstream. It then moved upstream and burrowed in the mud in the manner described by Cagle (1944b). It appears that in periods of severe drought, snapping turtles do not move in a concerted fashion to a more congenial habitat.

Home ranges. It appears that snappers have home ranges that are large (1.33 ha), temporary (perhaps lasting a season), and overlapping implying that they are not strongly defended against other snapping turtles. Froese (1974) found the 11 turtles he followed had overlapping home ranges of 3.22 m^2-568.9 m^2 (average 216 m^2), much smaller than those of the snapping turtles in the present study. However, Froese's turtles were confined to a 0.81 ha pond and Moll and Legler (1971) indicated that aquatic turtles home ranges are likely to be affected by size and shape of habitat. Ernst (1968b) estimated the home ranges of snapping turtles at 1.88 ha but did not compare the size of home ranges to aquatic area and shape. Hammer (1969) assumed snapping turtles had home ranges encompassing most of a single large pool. These pools were waterfowl management areas with 40-101 ha of aquatic habitat. It seems likely that snapping turtle home ranges are partially determined by size and shape of their aquatic habitat.

Data obtained from Chichaqua suggest that home ranges

are temporary, perhaps lasting a season. Most long distance movements took place in fall or early spring. Ernst (1976) found that from 1967 to 1974 there was much shifting of home ranges in the spotted turtle, Clemmys gutatta, and attributed this to normal ecological succession. As the marsh sedimented in, the C. gutatta that had home ranges there would be forced to move to a new location. Hammer (1969), in a marsh that did not dry up, found that snapping turtles moved an average of 0.07 miles when recaptured within a summer while recaptures between years averaged 0.57 miles indicating that snapping turtles often make, for no known reason, long distance movements in the fall or early spring resulting in a shift of home ranges.

Homing ability. *Snapping* turtles apparently have some homing ability. One turtle was observed to move from under a stump, 740 m east and 24 days later returned to this stump. TTs were repeatedly observed to return to a location after foraging. Froese (1974) found them returning to one or more homesites after periods of activity. This homing ability is also found in other species of turtle. Moll and Legler (1971) found that Pseudemys scripta had some homing ability and Williams (1952) indicated homing ability in other species of turtle. The data indicate that snapping turtles recognize their habitat and retain this memory for at least 24 days.

Population and density estimate. At Chichaqua

Wildlife Area the density of snapping turtles was estimated at 17/ha (95% confidence limit range of 13.4-20.4 turtles per hectare). Several things may have influenced this estimate. Turtles captured once may avoid capture in the future. This possible effect was minimized because about 50% of the turtles examined in 1977 were obtained by means other than trapping. Four were obtained by hand. Two were found, partially consumed by predators or scavengers, on the bank and seven were found dead floating on the water in spring 1977, due to the winter kill of the previous winter. Years 1976 and 1977 experienced low precipitation and resulted in the aquatic habitat of the marsh being smaller. The role this low water played on the density estimate is unknown and therefore the estimate should be regarded as tentative. In addition, the effect of immigration and emmigration is unknown but the effect is believed to be minimal because turtles could only enter the area where it adjoins the Skunk River and none of the six snapping turtles trapped in the river were marked.

Other estimates of snapping turtle density have varied greatly. These include, Froese and Burghardt (1975) 59/ha, Lagler (1943) 5/ha, Hammer (1969) 1.2/ha, and Major (1975) 60.5/ha. While differences in density undoubtedly reflect habitat differences, it is interesting to note that the estimates above 15/ha were the result of extensive trapping. Froese and Burghardt (1975) trapped from April

to October. Major (1975) trapped from May to October and in the present study trapping was conducted over two years. Froese (1974) and the present study indicated that snapping turtles are inactive most of the time. Thus it is probable that only by extensive trapping can a reasonably reliable estimate of population density be obtained.

SUMMARY AND CONCLUSIONS

Studies of marked central Iowa population of Chelydra serpentina indicate that shell growth begins in the last two weeks of May. Turtles captured before that time will have the same age as turtles captured in summer of the previous year if aged by use of annulae. Most rapid growth is in June, July, and August. This growth is accomplished in an activity period of 204 days and a 145 day feeding period. Data from preserved Iowa snapping turtles show that males mature in the fourth or fifth year of growth at plastral lengths of 149-155 mm. It appears that females enter a period of ovarian follicle development without ovulations between years four and seven and plastral lengths of 123-172 mm with the smallest mature female of 172 mm PL. Ovulation first occurs during the sixth or more often in the seventh full year of growth or later.

Growth is greater and more variable in juveniles but once maturity is reached, growth and variability are reduced. Males grow at a considerably faster rate than females

during years 5, 6, and 7 and some males continue to grow measurably beyond 35 years. Female growth is slight beyond 20 years. Male growth rate decline is strongly correlated with maturity but this decline in females is less abrupt and begins much earlier at the start of ovarian follicle development. In past studies utilization of enlarging follicles as a criterion for maturity may have masked differences in maturation age and size.

Snapping turtles prefer congested sites to open ones. This preference was also found in hibernating turtles. When available beaver lodges seem to be preferred.

Juveniles are found in approximately equal numbers to adults. It appears that there is a shift in sex ratios from females being more frequent as juveniles to males being more frequent as adults but the evidence presented by others makes this inconclusive.

It appears that snapping turtles have an activity period of 204 days and an estimated feeding and growing period of 145 days shorter than the other common turtle in the state. It appears that adult males become active at least several weeks before females and juveniles although the evidence is not substantial.

Snapping turtles apparently bask aerially primarily in spring when the water is cool and they seldom bask either aerially or in water after June. This decreased basking may result from increasing water temperatures and a reduced

need for thermoregulative basking.

The data suggest that snapping turtles exhibit the following behavior when the habitat dries up. They burrow deeply in mud in most cases and occasionally burrow terrestrially. When buried terrestrially, they prefer low shaded locations where conditions would be more favorable. They remain buried until conditions improve, such as a significant rain or refilling of habitat. If they do move while the habitat is dry, they prefer to do it during rainy periods when conditions of humidity and temperature would be more favorable. They are significantly less active during these periods of severe drought. This behavior presumably decreases mortality due to overheating and desiccation during severe drought conditions.

It appears that snapping turtles have home ranges that are large (1.33 ha average), temporary (perhaps lasting a season), and overlapping implying that they are not strongly defended against other snapping turtles. They apparently have some homing ability or ability to recognize their habitat and they retain this memory for at least 24 days.

The density estimate at Chichaqua Wildlife Area was 17 turtles per hectare. Because snapping turtles are inactive most of the time, reasonably reliable density estimates can be obtained only by extensive sampling of the area.

LITERATURE CITED

Anderson, P. 1942. Amphibians and reptiles of Jackson County, Missouri. Bull. Chicago Acad. Sci. 6(11):203-320.

Baldwin, R. M. 1926. Notes on the oxygen consumption in turtles, Chrysemys marginatta belli and Chelydra serpentina Linn. Proc. Iowa Acad. Sci. 33:315-325.

Brown, R. 1969. Snapping turtles. Herpetology 3:9-12.

Cagle, F. R. 1944a. Sexual maturity in the female of the turtle, Pseudemys scripta elegans. Copeia 1944(3): 149-152.

_____. 1944b. Home range, homing behavior, and migration in turtles. Misc. Pub. Mus. Zool. Univ. Mich., No. 61, Nov. 21, 3-37.

Cahn, A. R. 1937. The turtles of Illinois. Illinois Biol. Monogr. 16:4-217.

Christiansen, J. L., and A. Dunham. 1972. Reproduction of the yellow mud turtle (Kinosternon flavescens flavescens) in New Mexico. Herpetologica 29:152-163.

Clark. H. W., and J. B. Southall. 1920. Fresh-water turtles: a source of meat supply. Bureau of Fisheries Document No. 889, Govt. Printing Office, Washington.

Collins, J. T., J. E. Huheey, J. L. Knight, and H. M. Smith. 1978. Standard common and current scientific names for North American amphibians and reptiles. Soc. Study of Amphibians and Reptiles. Misc. Publ. Herpetologica Circ. No. 7.

Cooper, J. A. 1975. Behavioral aspects of the life history of the Illinois mud turtle, Kinosternon flavescens spooneri. M. A. thesis Drake Univ. 56 pp.

Ernst, C. H. 1968a. Evaporative water-loss relationships of turtles. J. Herpetology 2(3): 159-161.

_____. 1968b. A turtle's territory. Int. Turtle and Tortoise Soc. J. Nov.-Dec.:9, 34.

_____. 1976. Ecology of the spotted turtle, Clemmys guttata, (Reptilia, Testudines, Testudinidae), in southeastern Pennsylvania. J. Herpetology 10(1):25-33.

_____, and R. W. Barbour. 1972. Turtles of the United States. Univ. Press Kentucky, Lexington. 347 pp.

_____, R. W. Barbour, and M. M. Hershey. 1974. A new coding system for hardshelled turtles. Kentucky Acad. Sci. 35:27-28.

Ewert, M. A. 1976. Nests, nesting, and aerial basking of Macroclemys under natural conditions and comparisons with Chelydra (Testudines: Chelydridae). Herpetologica 32(2):150-156.

Feuer, R. C. 1971. Ecological factors in success and dispersal of the snapping turtle, Chelydra serpentina (LINNAEUS). Bull. Philadelphia Herp. Soc., 19.

Finneran, L. C. 1948. Reptiles at Branford Connecticut. Herpetologica 4(4):123-126.

Fitch, H. S. 1958. Home ranges, territories, and seasonal movements of vertebrates of the natural history reservation. Univ. Kans. Pub., Mus. Nat. Hist. 11(3):63-326.

Froese, A. D. 1974. Aspects of space use in the common snapping turtle Chelydra s. serpentina. Ph.D. dissertation, Univ. of Tenn., Knoxville. 96 pp.

_____, and G. M. Burghardt. 1975. A dense natural population of the common snapping turtle Chelydra s. serpentina. Herpetologica 31:204-208.

Gentry, G. 1956. An annotated checklist of the amphibians and reptiles of Tennessee. J. Tenn. Acad. Sci. 31(3): 242-251.

Gibbons, J. W. 1968a. Reproductive potential, activity, and cycles in the painted turtle, Chrysemys picta. Ecology 49:399-409.

_____. 1968b. Growth rates of the common snapping turtle Chelydra serpentina in a polluted river. Herpetologica 24(3):266-267.

_____. 1970. Terrestrial activity and population dynamics of aquatic turtles. Amer. Midl. Nat. 83:404-414.

Graham, T. E., and R. W. Perkins. 1976. Growth of the common snapping turtle, Chelydra s. serpentina, in a polluted marsh. Bull. Maryland Herp. Soc. 12(4): 123-125.

Hammer, D. A. 1969. Parameters of a marsh snapping turtle population, Lacreek Refuge, South Dakota. J. Wildlife Management 33(4):995-1005.

_____. 1972. Ecological relations of waterfowl and snapping turtle populations. Ph.D. dissertation, Utah State Univ., Logan. 72 pp.

Hutchison, V. H., A. Vinegar, and R. J. Kosh. 1966. Critical thermal maximal in turtles. Herpetologica 22:32-41.

Kezer, L. J. 1937. A preliminary survey of the fish, amphibians, reptiles, and mammals of an area in the vicinity of Summit, New Jersey. M. S. thesis, Cornell Univ., Ithaca. v, 113 pp.

Lagler, K. F. 1943. Food habits and economic relations of the turtles of Michigan with special reference to fish management. Amer. Midl. Nat. 29:257-312.

Legler, J. M. 1960. A simple and inexpensive device for trapping aquatic turtles. Proc. Utah Acad. Sci., Arts, Lett. 37:63-66.

Mahmoud, I. Y. 1969. Caparitive ecology of the kinosternid turtles of Oklahoma. S. W. Nat. 14:31-66.

Major, P. D. 1975. Density of snapping turtles, Chelydra serpentina in western West Virginia. Herpetologica 31(3):332-335.

Moll, E. O., and J. M. Legler. 1971. The life history of the neotropical slider turtle, Pseudemys scripta (Schoepff), in Panama. Bull. Los Angeles Co. Mus. Nat. Hist. No. 11, 102 pp.

Mosby, A. S., ed. 1963. Wildlife investigational techniques. Wildlife Soc., Ann Arbor, Michigan, 419 pp.

Mosiman, J. E., and J. R. Bider. 1960. Variation, sexual dimorphism, and maturity in a Quebec population of the common snapping turtle, Chelydra serpentina. Can. J. Zoology 38:19-38.

Murphy, G. G., and J. F. Sharber, Jr. 1973. Preliminary analysis of activity of the common snapping turtle. Chelydra serpentina, as determined by biotelemetry. J. Tenn. Acad. Sci. 48:56.

Pope, C. H. 1939. Turtles of the United States and Canada. Alfred A. Knopf, New York.

Sexton, O. J. 1959. Spatial and temporal movements of a population of the painted turtle, Chrysemys picta marginatta (AGASSIZ). Ecol. Monogra. 29:113-140.

Stickel, L. F. 1950. Populations and home range relationships of the box turtle. Ecol. Monogr. 20:353-378.

White, J. B., and G. G. Murphy. 1973. The reproductive cycle and sexual dimorphism of the common snapping turtle, Chelydra serpentina serpentina. Herpetologica 29(3):240-246.

Williams, J. E. 1952. Homing behavior of the painted turtle and musk turtle in a lake. Copeia 1952:184-186.

Wood, J. T. 1953. Protective behavior and photic orientation in hatchling snapping turtles, Chelydra serpentina serpentina (LINNE), in an aquatic environment. J. Elisha Mitchell Soc. 69:54-59.